TELESCOPE MAKING 44

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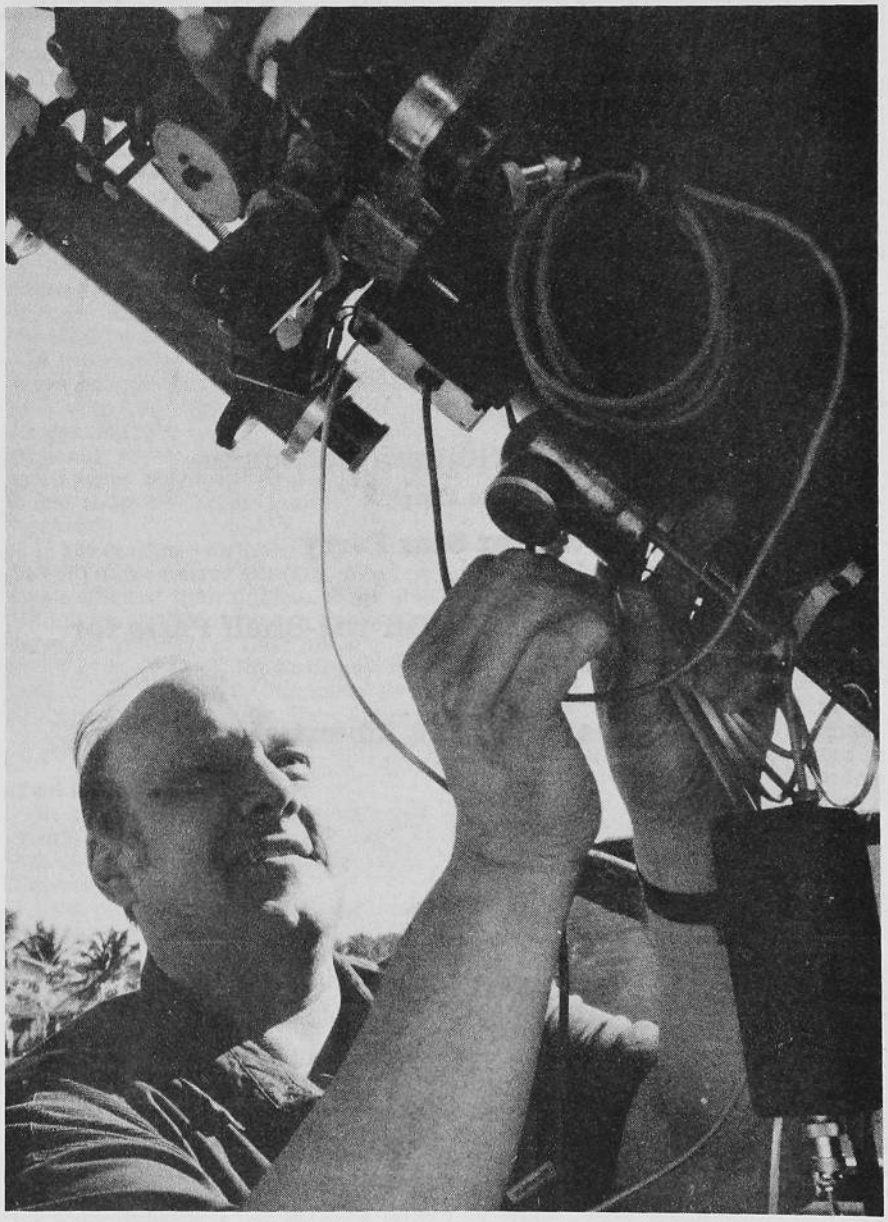
The magazine *for*, *by*, and *about* telescope makers! **Spring 1991**

- **Building a 6-Inch Brass Refractor**
- **Color-Free Apochromatic Doublet**
- **Obsessive Telescope Building**
- **Tom Clark's 30-Inch Dobsonian**
- **Florida's 1991 Winter Star Party**



Telescope Making #44

The magazine *for*, *by*, and *about* telescope makers!

Editor: Richard Berry
Associate Editor: Peter Ceravolo

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Cover: Planetary photographer Don Parker of Miami, Florida prepares his telescope for a night of observing. Don's 16-inch Newtonian has long produced planetary photographs that rank among the finest in the world; it now produces CCD images that rival professional ground-based planetary work. Photo by Richard Berry.

Editorial

The Letters section in this issue of *Telescope Making* is devoted almost entirely to responses to Marschall Nunlist's letter and to my editorial request for your comments about *TM*. We haven't had such a flood of mail, faxes, and phone calls since... heck, I don't know when.

Let me first reassure you that *TM* is not about to take some radical turn toward simple-minded articles. Remember that the stories in *Telescope Making* are written by you and by people like you, and you aren't likely to start writing that kind of story regardless.

Second, *TM* has achieved its position and its present circulation (of 8,000 readers!) because it is devoted to what you're interested in reading and learning about. I do not believe we could find any greater success by abandoning the current readership and going in search of some hypothetical readership of people only marginally interested in building telescopes.

Third, there's a clear need for stories that have their *greatest* value for beginning telescope makers. To my mind, that does not imply that such stories should have no value for the "old hands" of telescope making, but that these stories not exclude newcomers.

Many thanks to all those who wrote. And remember this: we're always interested in your input.

Richard Berry

Letters

Cry of "Foul"

Mr. Berry/ I am writing with regard to the letter you received from Marshall B. Nunlist. By no means do I consider myself an advanced *TM* but I do cry foul. The mere thought of watering down of articles so they become more palatable to a larger readership is sheer folly. If individuals have trouble understanding optical write-ups, this should spur them on into researching the subject further, through books, magazines and so forth easily found in their local libraries and book stores.

Of course, if they happen to belong to an astronomy club they could ask a member. People in the hobby are always willing to listen and provide helpful advice. Then when all is said and done, they should have a far better understanding of the concepts and principles involved in describing optical equipment. But to change the format of a highly regarded publication just to pander to the few who lack initiative is just plain dumb.

When I bought my first issue of *TM* it was as though I had found a piece of gold. Finally I had my hands on a magazine that dealt with the needs of the real builders and tinkerers out there. Like I mentioned earlier, books on the basics can be bought, but books on the latest breakthroughs cannot. By the time that "new" book comes out, it is already old.

The purpose of *TM* is to advance the art of telescope making — with the emphasis on "advance" — and to promote growth in a field through the sharing of new ideas and concepts. *Telescope Making* provides the catalyst for someone to boldly build a telescope which no man has built before.

Louie Pascos
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L0L-1W0 Canada

Both Optics and Mechanics

Just received my *TM#42* and in response to your editorial and Mr. Nunlist's letter I am sending you my feelings. I do enjoy the advanced articles, though sometimes they are over my head. But I regard those articles like money in the bank. They are much needed and should not be omitted by any means. In addition I would like to see articles on things like drilling holes in Cassegrain blanks, differences in optical pitches, simple lens making, permanent piers, equatorial drives, stepper motors,... I think you get the idea.

Although optics is the heart of amateur telescope making, the mechanics are also quite important and of great interest to all TMs. I have been a subscriber to *TM* since *TM#26* and recently bought all the back issues I could. However, there are still nine issues I am unable to buy as they are out of print. By looking at the index that was printed in *TM#29* I can see that the articles I would love to read on lens making and permanent piers are in the issues I am unable to get.

In summary, I feel that *TM* should have articles on both advanced and basic telescope making in each issue, thus giving something for everyone. You might even consider reprinting some of the better articles from the issues that are out of print.

Dave Bloomsness
P.O. Box 801
Ashland, OR 97520

Sense of Foreboding

After reading Mr. Nunlist's letter and your question to readers in *TM#42* I was filled with foreboding. I for one do not want to see *TM* turned into a platform for neophytes.

The libraries and bookstores have many volumes on the subject. *S&T* and ASTRONOMY are filled with articles about basic telescope fabrication. Please, please do not corrupt *TM* with pieces on copyscopes, second-rate Dobsonians and wooden observing chairs.

TM is the sole English source for advanced telescope ideas. People can get simple mirror-making instructions from 100 different references.

I realize that ASTRONOMY has always catered to the beginner. *S&T* is now doing the same. Worse yet, these magazines are trying to attract the amateur whose sole motivation is to get a scope as cheaply as possible. Do I see more PVC-pipe finders on the horizon?

If *TM* readers can offer hints about how to make mirror grinding easier or more efficient then publish them, but I don't want *TM* to cater to those who have not yet learned their ABCs.

Richard Anderson
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Two Cents on Beginners

In response to your call for comments from newcomers to *TM*, I would like to take this opportunity to get my two-cents worth in.

First of all I'd like to say after reading my third issue (*TM#42*) that I do enjoy the publication and am thankful that a magazine is available to serve such a special interest group as TMs.

Now, on to what kind of stories I'd like to see published, a short list follows.

- Actual construction techniques, such as the article on constructing foam and fiberglass tubes. Such articles help readers in the real task of telescope making whereas stories on the HST — although interesting — don't.
- Product or service comparisons, like who does the best aluminizing and is it possible to deposit multilayers, i.e., enhanced coating, without altering the figure. Most services and telescope components are available to ATMs only by mail order. It is therefore next to impossible to do any real comparative shopping for items like focusers or mirror mounts. We ATMs could use some help in selecting quality products and services.
- A telescope maker's swap table. Perhaps you could devote one of your Blue Pages to readers who either have used components for sale or are looking for parts.

In closing I'd like to thank you for the opportunity to voice what I'd like to see published in *TM*. In reference to Mr. Nunlist's letter, I somewhat agree with him. We must remember that the A in ATM stands for amateur and by keeping things simple and as inexpensive as possible, we can insure future generations of telescope makers. I also think a good mix is quite possible to keep both the beginner and those of us who have several mirrors under our belt reading with enthusiasm.

Bob Chester
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Wish List Plus Tip

Perhaps I don't qualify as the relative newcomer, but certainly there is room in the novice category for me. So in response to your request for what topics we like to see more stories on, here are a few suggestions:

- Optical fabrication;
- Optical testing;
- New optical designs;
- Design and fabrication of telescope tubes and mounts.

Under the heading of articles, I would like to see the following titles in the future:

- Understanding spot diagrams;
- Stepper motors for telescopes;
- Optical test equipment and tools.

By the way, here's a tip for telescope makers or anyone interested in stepper motors: the All Electronic Corp. (phone: 800-826-5432) offers a stepper motor controller kit (with motor) for $18.00. This is an easy kit for somebody (like me) new to the soldering iron. I changed the 100kΩ variable resistor to a 500kΩ variable to achieve the 1 rpm rate I needed.

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Don't Degenerate!

Each issue of *Telescope Making* magazine is a gold mine of valuable and innovative information. It is a primer for new ideas and a catalyst for discussion between TMs. I was therefore saddened to read Marshall Nunlist's letter in *TM#42*.

Letters

Changing the magazine to make it more appealing to a larger audience is a mistake. For one thing it dilutes the uniqueness of each article. Popularization of astronomy and telescope making at the elementary level is a job for ASTRONOMY and *Sky & Telescope*.

If Mr. Nunlist needs an elementary treatment of optics fabrication, a visit to a good library would be in order. There are at least ten books that I know of on the subject. What's the point of rehashing old material?

When I first started out in this hobby I found these books very useful. Unfortunately, the older books have become dated and *TM* now serves as a supplement to these books. If every TM picked up only the popular Ingalls books, we would be stuck forever in the 1940s.

Now, only after 15 years in the hobby, do I realize all the errors and half-truths in those books. Many people believe that making your own optics is better than buying them. This is true only if one knows his subject well. The older books don't tell you the whole story! Where else but in *TM* would I have found out about the Dakin version of the Foucault test, or the Ross Null test, or thin mirror fabrication?

If *TM* degenerates to the level of a beginners rag, then it would be a great disservice to the amateur astronomical community. Let's not let this happen.

As for commercial manufacturers pressuring people to buy scopes, this is not true. Telescope companies offer a reasonable alternative to those who do not wish to build scopes. The customer is the one who decides.

Progress comes from new ideas and results in change. Innovation must continue!

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More Optical Fabrication

Dear Mr. Berry/ As a reader of *TM*, I look especially to the pages that deal with the fabrication of optics. I wish there were more of them in each issue. The readers of this magazine probably have many books on this subject, but it is still good to hear new and personal experience from those doing such projects. I would like to see more articles presented in "cookbook" fashion, heavily documented, on optical work done with common materials, techniques and test methods. These articles would be relevant to a range of telescope types — the various Cassegrains, TCTs, and refractors — as well as the standard Newtonian.

Advanced subjects such as ray-tracing, design, machined mountings and high-tech testing should remain. This subscriber is willing to pay for a bigger or more frequent publication to hold it all.

If there is a single subject that needs concentrating on, from my standpoint as well as all I speak with, that subject is the making of a good PITCH LAP. A lot of mirrors out there never get past this stage. They await a best, simplest, sure-fire, get-it-on-the-first-try method of making one.

There is no room for trade-secrets of ANY kind in the making of astronomical equipment. As an example of this spirit of sharing, I cite John Dobson who gave all of us a mounting and a CONCEPT for big apertures and demanded nothing material in return. It was a thrill to watch him speak and demonstrate at Stellafane in 1987. Your coverage of events like these, nationwide, is excellent — please keep it up.

I am still a beginner in this hobby, but I hope to someday submit articles to this publication. I most certainly do not consider myself in competition with the commercial manufacturers of telescopes. In closing, I feel there will always be a need for this kind of magazine and the hobby it serves.

(unsigned)

Help the Beginner!

I agree with Marshall Nunlist *TM#42* that basic mirror making and testing articles would help beginners. I also think if TMs are made and not born that you had better as a group start looking for new recruits or expect to end up like the passenger pigeon!

As a tyro amateur astronomer and a new subscriber to *TM* I have little to none in the experience category. It was not until the 25th of this January that I have had the opportunity to even look through a reflecting telescope of any size (a 10-inch Meade SCT and a couple of 6-inch Newtonians). These were at a public stargaze put on by the newly formed astronomy club in this area.

I would dearly love to own a telescope. However, on my budget the only way to do that will be to make one myself.

I have gleaned some good ideas from *TM* that I would like to incorporate in a telescope. I personally need more information dealing with basic optics as well as fundamental mirror making and testing in order to successfully make a telescope on my own.

Please remember that all of you advanced amateurs started from zero at some time and new TMs have to learn, too!

Dave Wattles
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Already Helping Beginners

Richard/I agree with both Marshall Nunlist's and Peter Wraight's statements in *TM#42*. The computerization of a once simple hobby has left me, as a beginning TM, feeling lost. The notion of building a scope overwhelms me. And Stellafane, where I saw simple instruments, only served to remind me of the future shock I feel.

"Listen world," cried out this beginning telescope maker. "I only wish to learn how to build an 8-inch scope with a simple but effective clock drive."

Silly as this may sound, stories about such simple projects are rare. I realize that there are those who are far beyond the basics and I sympathize with them. Without their inventiveness telescope making would soon become mundane. But were it not for beginners such as myself, what future would the art of telescopoe making have in this computer age?

I have read some excellent articles in *Telescope Making* and only hope that you'll continue to help us beginners still interested by printing more how-to articles.

Michael Mendoza
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Lesson from Hubble

The articles by Peter Ceravolo, David Shafer and David Stoltzman provided an excellent insight into the problems and possible solutions associated with the ill-fated Hubble Space Telescope.

Since the launch of the HST and discovery of its faulty optics, NASA has partially succeeded in correcting the HST's imaging error by computer optimization which yields pictures that apparently surpass in detail the best photographs taken from Earth, although they still fall short of the resolution possible if the optics were flawless.

There is every reason to believe that the HST problem can and will be corrected. However, what can't be repaired is the fact that the developers of this project, both at Perkin-Elmer and at NASA, neglected a simple, self-evident truth that applies to every telescope equally and without exception: it's only as good as the image it delivers at the focus.

As amateurs, we should learn a lesson from the HST's misfortune, and that is not to trust our test results absolutely. We must confirm the results of one test with another completely different test. Above all, we must remember—because our tests are finite and imperfect—that telescopes are not a simple sum of their parts (except those on paper!), particularly compound telescopes like the HST.

Mladen Vranjican
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Why Don't Mirrors Flow?

Richard/ When we figure an optical surface, we expect the glass to retain its exact form indefinitely to a tiny fraction of the wavelength, just as it was when it last touched the polishing lap. After all, isn't it a fact that glass holds its shape forever?

Many of us have seen the sagging glass tops in café tables of the old-fashioned type which have discs of class supported by a peripheral iron frame. With time, the glass sags in the center to a degree quite easily visible to the unaided eye.

Thus it is perfectly plain that glass can and does change its shape, given time and application of stress. This fact is absolutely undeniable.

Let us suppose that over the course of twenty years, a twenty-inch plate-glass café table top 1/3 of an inch thick sags half an inch in the center as compared to the edges. I have seen such tables with my own eyes and probably you have seen them yourself. Note that a wavelength of green light is one fifty-thousandth of an inch. We can readily calculate that the glass has sagged 25,000 wavelengths in 20 years, 1,250 wavelengths in a year, or 3 waves per day!

Suppose you've just figured your thin plate-glass mirror to 1/20 wave precision. How long do you think that it will hold its shape? Oh yes, you're supporting it very carefully, with hardly any stress at all. Suppose that you're supporting it so carefully that you're applying only 1/250 the stress that the glass would encounter in the café table configuration with edge support alone. In 20 years you'd still see a sag of 100 waves!

Well, even thin telescope mirrors are a lot thicker than café tables, and that also makes them more resistant to sagging with time. Suppose that your thin mirror is 50 times stiffer than a café table — now in 20 years your beautiful 1/20-wave mirror sags until it's 5 waves off. That's a 1/4-wave error in just one year. Does this mean that great optics can go to pot completely in just a few years.

In the past, the change of mirror figures with time was accepted as just one of those things. Sir Howard Grubb in his recently republished memoirs (imagine a small paperback book costing $75, which it does!) states that some optical surfaces in his shop would lose their figures at a rate greater than a wavelength a year, and these were small reference blocks, far more stable than our large thick plate-glass mirrors. In ATM Book I, Ellison described a mirror that would perceptibly lose its figure within a few hours. It would seem that in recent decades, these lessons have been forgotten. Perhaps we were all spoiled by those grand old molded Pyrex blanks with the sloping sides and the edge on the back edge and the careful annealing. After all, for decades practically no one worked with plate glass or sheet Pyrex.

There are bound to be people out there who are sniffing disdainfully and saying, bah humbug, everybody knows that glass doesn't change its shape with time. It's things that "everybody knows" that get us in trouble.

The first step toward solving any problem is to become aware that the problem exists. Glass sags. So let's start talking to each other about sagging glass. Has anyone out there had a plate- or sheet-glass mirror that lost its figure in a few weeks or a few months? Maybe it was the glass. The more information we have about this problem, the better we'll be able to cope with it. We cannot afford to lose our eyes to this problem. The sagging café tables won't go away!

Herbert Highstone
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Monte Rio, CA 95462

— Herb raises an interesting question here. Has anyone done the math to see why café tables sag and why mirrors don't — or do they?

Star Testing

Richard/I would like to clarify to your discussion of the star test on page 45 of *TM#43*. In *TM#32*, I mentioned that the focused stellar image is very sensitive to errors in the wavefront. The problem with evaluating optics at best focus has more to do with the style of test and interpreting it. The problems split among several categories.

(1) The errors manifest themselves as extra intensity in the diffraction rings. The trouble with this is that the eye is a poor absolute photometer; it needs a comparison image. Symmetric aberrations are hard to discern.

(2) Often the focused test method used is the resolution of nearly identical double stars. This is okay as far as it goes, but common aberrations do not manifest themselves in degradation at the very high spatial frequencies of interest in double star resolution. Images of most interest are often low-frequency that transfer badly through aberrated systems. Double-star tests often don't betray these poor telescopes.

(3) The focused image can be badly disturbed by atmospheric turbulence. Slightly defocused images are bigger and, more importantly, turbulence can usually be identified and isolated in them.

(4) It is difficult to tell exactly what is wrong with a focused image, only that it is poor. Defocused images will often betray not only the presence of aberration, but its origin.

Focused images suffer badly in the presence of aberrations but I, for various reason, find the defocused image easier to work with.

Dick Suiter
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LAAS Correction

Richard/Thank you for the complimentary copies of *Telescope Making #43*. It is quite a thrill to get something published. I did notice two places where the article is unclear.

In the first paragraph under the heading "History," the last sentence should read: "In the spring of 1987, members of the LAAS drove the mirror home from New Mexico to Los Angeles." In the fourth paragraph under the heading "Hardware Interface," the first sentence should read, "The software limits the pulse rate to a predetermined threshold (175 pulses per second in our case) to prevent the motors from driving the telescope too fast." I realize these are only minor corrections but I wanted to pass them along.

Michael Schettler
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Ooops!

In "Variations on the Schiefspiegler," by Jose Sasian (*TM#43*) we inadvertently left out the bibliography. Here it is:

(1) A. Kutter, Der Schiefspiegler, Fritz Weichlard, Biberach and der Riss, 1953. The historical note given above is based on a translation of the introduction of this book that Ms. de Colstoun kindly prepared.

2) A. Kutter, The Schiefspiegler, *Sky & Telescope* Bulletin A , (no date).

(3) R. Buchroeder, Design examples of tilted-component telescopes (TCTs), Technical Report 68, Optical Sciences Center, University of Arizona, 1971.

(4) R. Berry, Computer simulation of the Airy disk for obstruction ratios from 0.0 to 0.8, *TM#40*.

(5) R. Suiter, Modifications to the diffraction image caused by surface roughness in mirrors, *TM#38*.

(6) J. Sasian, "A practical Yolo telescope," *Sky & Telescope*, August 1988.

(7) R. E. Pressman, "An Experimental Compound Reflecting Telescope," Journal of the British Astronomical Association 57 (6) 224.

(8) The accompanying Schiefspiegler photo is a courtesy of R. Buchroeder.

The figures for Table 3 should read: f/# = 25.4; Rpri = 2880.43mm; Rsec = 5069.56mm; Dp = 108mm; Ds = 95mm (0.5° field); Tilt pri = 26°; Tilt sec = 40.70°; Ti = 238.43mm; T2 = 2316mm; Image plane tilt = 5.2°; Image anamorphism = 1.4°.

In Peter Ceravolo's "Stellafane '90" story, please note that the maker of the "zoomer ball" is actually Chuck McLaren, and his part is called a Boomer Ball. McLaren lives in Landenberg, PA. Sorry about the mix up in the names.

And finally, we misspelled Veikko Kanto's name (it's not an "i before e except after c" word!) in *TM#43*. Once again, our sincere apologies.

Constructing a Large Brass Refractor

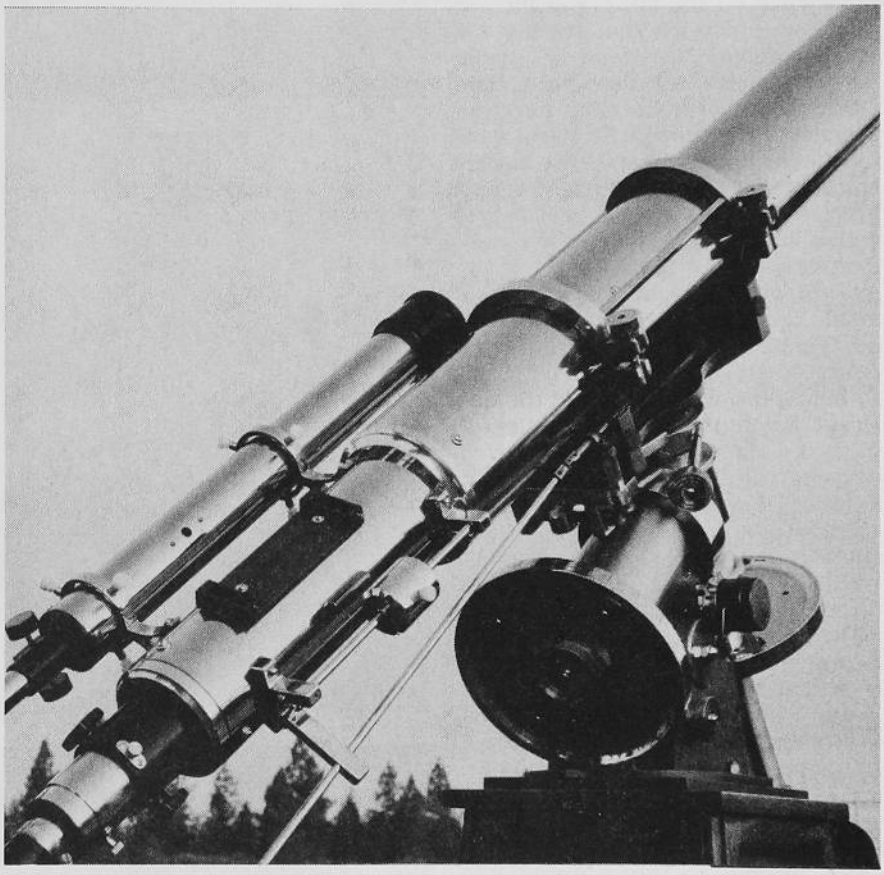
Because I've been a diehard astrophotographer for a number of years, constructing a large refractor was the last thought on my mind. Besides I'm no machinist, and I'm not nearly as resourceful as some of my friends. Anyway, what could I do with a refractor that I couldn't do with my 11-inch SCT?

Then one dark night at the Henry Grieb Observatory, owned by the Sacramento Valley Astronomical Society, my mind was changed. While I was using the club's 16-inch Ritchey, I took a quick look through the 3-inch finder. I was blown away by the view. While I had, on occasion, observed with refractors, I had never stopped to "smell the roses." I just couldn't get those crisp, contrasty images out of my mind. I then knew I had to have one.

Then reality set in. I couldn't afford a quality refractor, I told myself, and I wasn't sure I could build one. I put the whole idea out of my mind.

In May 1989, at the RTMC swap meet, the situation again changed. There I found myself trading my old, dusty, unused, Comet Catcher for a 6-inch f/12 objective lens. It had an impressive-looking crown and flint encased in a beautiful brass cell. All I had to do was to design and build a telescope around it. My worries were over and my life complete.

There was just one small hitch — how was I to go about building the telescope? Prior to the RTMC I had acquired a small used lathe and mill, but I had no idea how to use them. So first things first: I enrolled in a machine-shop course at the local community college. After one semester I felt comfortable enough to start, but notice that I said "comfortable enough" and not "knowledgeable enough." Shortly into construction I upgraded to a precision engine lathe.



Brass gleams in the afternoon sun, and Larry Myers prepares for a night with his new refractor. Larry learned machining to build this telescope.

The design of the instrument was the next thing I had to think about. I have always loved the old turn-of-the-century styles — there's something about the gleam of polished brass! I wanted a design that combined a bit of the old with a bit of the new. In theory this sounded fine, but it was quite a different story when I actually put the pencil to it.

Many hours later, after poring through every back issue of ASTRONOMY, *TM*, and *S&T*, and every book in my small library, I had some ideas. I decided that my refractor would be permanently mounted on a solid and massive mounting, a mounting too heavy to be portable. And since it was to be permanently mounted, the mount would be an equatorial. And, in keeping with the older, traditional designs, it would be a German equatorial. I wanted to go for the best instrument I was capable of building even though I knew it would be expensive.

All in all I spent in the neighbor-

hood of 50 to 75 hours drawing very precise plans. At that point I thought I would be able to follow my plans to the letter. Was I ever in for a rude awakening! My lack of knowledge concerning aluminum plate, brass tubing, and so on forced me to alter my plans innumerable times. The next time around — did you notice the way I said that? — I will do some heavy-duty homework prior to the design stage.

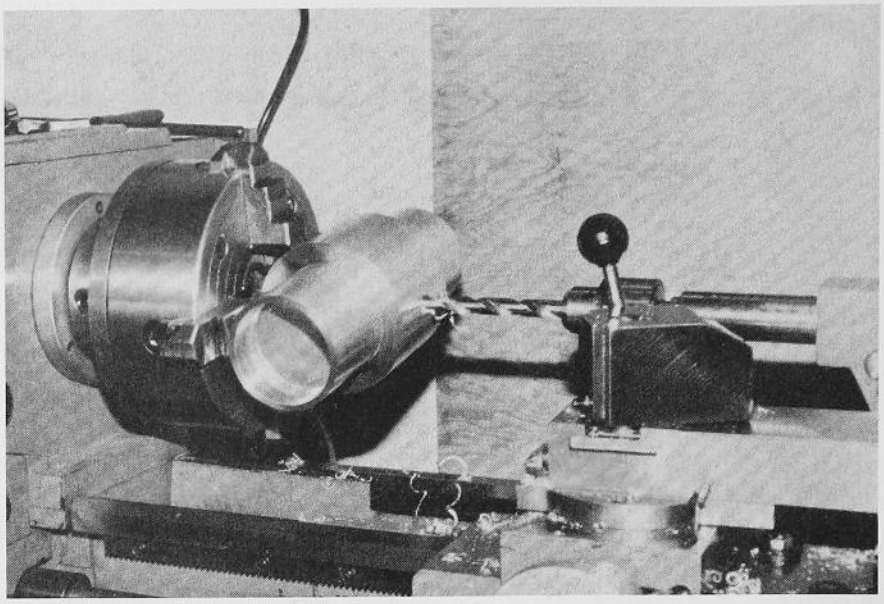
Construction

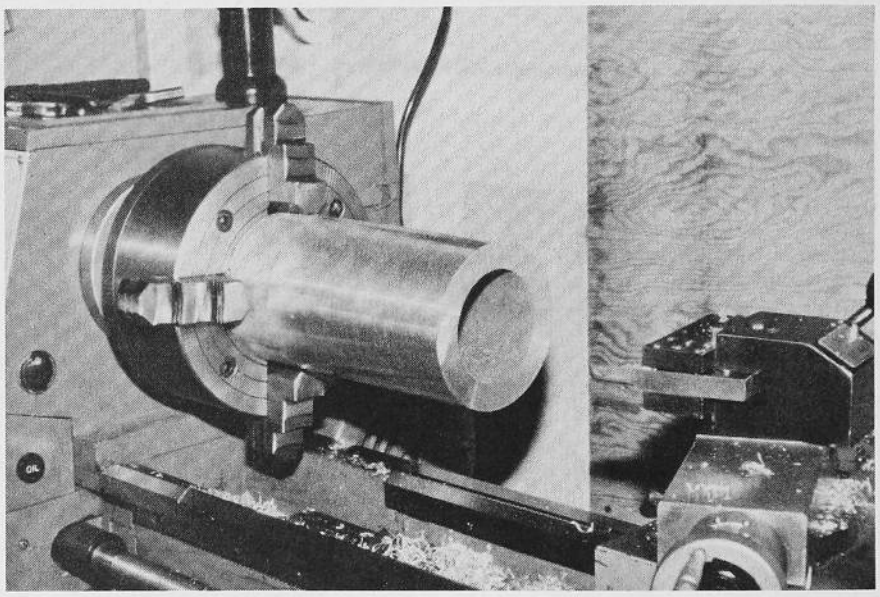
Because I was somewhat unsure of myself, I decided to start on the finderscope to gain much-needed experience on the lathe and milling machine. I also felt that starting on small components would be easier than on large. As I discovered, that wasn't necessarily the case. In retrospect, many of the smaller parts were as difficult to machine as the larger. Incidentally, I scrapped the finder I built as too heavy, and replaced it with a small Meade bought at Riverside for a song and a dance.

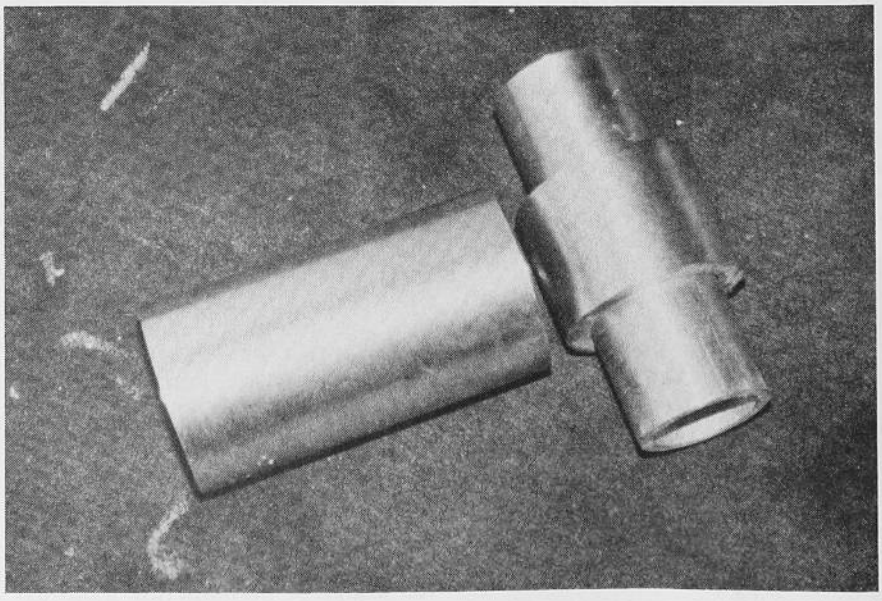
Over the years I had been given a small quantity of cast aluminum, all sizes and shapes. I had also purchased plate aluminum as I needed it. I soon began to recognize the different machining characteristics of various alloys. Some I enjoyed working with and some I didn't. In addition, I began collecting an odd assortment of brass scraps. My employment places me in contact with large industrial plants throughout northern California, and with a bit of sweet-talking their maintenance shops, I was soon collecting all kinds of materials.

Soon thereafter, I went to work on the main cell. It consists of three components: an outer "bell," an inner push-pull collar, and a brass objective housing. As can be seen from the pictures, hogging out that much aluminum was a formidable task. But before I could start the cell, I needed to have the main tube on hand. It was tough, but I eventually located a brass tubing supplier in the Bay area that handled large enough sizes.

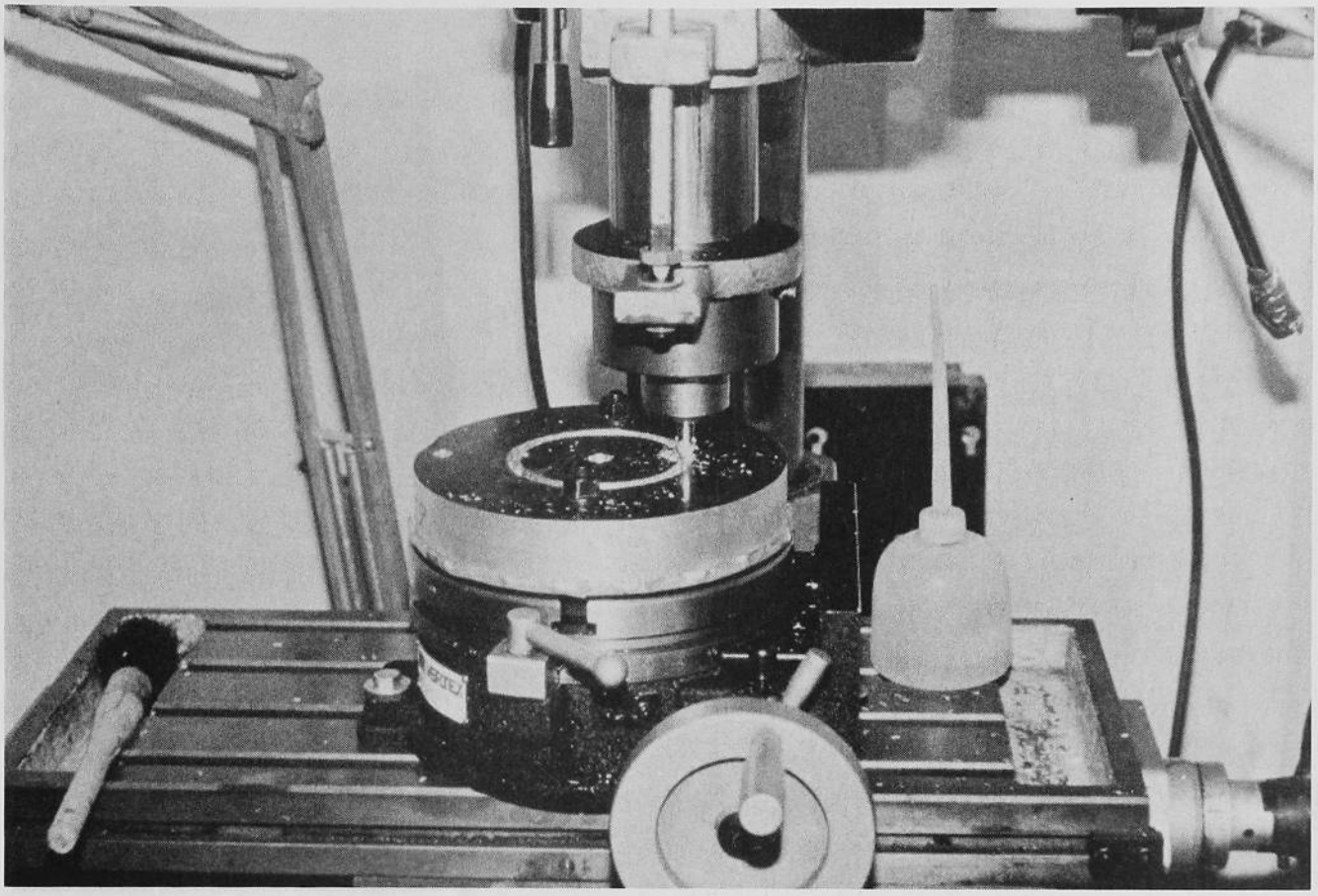
Coordinating my own efforts proved tricky because so many parts required other parts for proper fit. And those parts required even others. In fact, the age-old



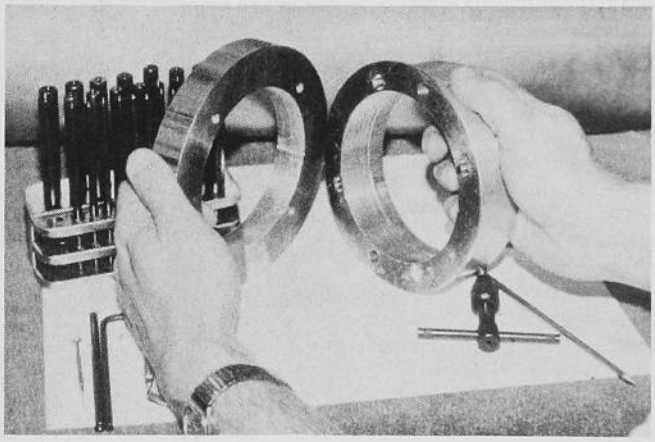


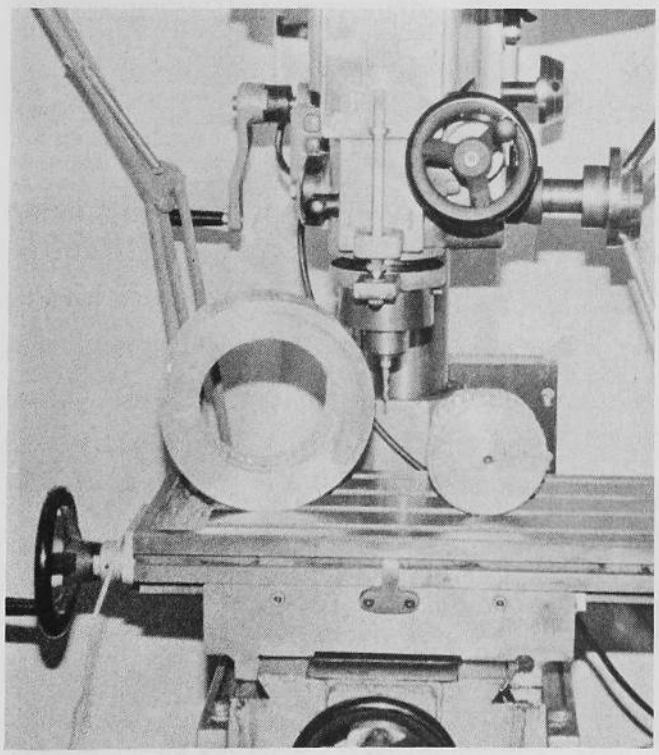


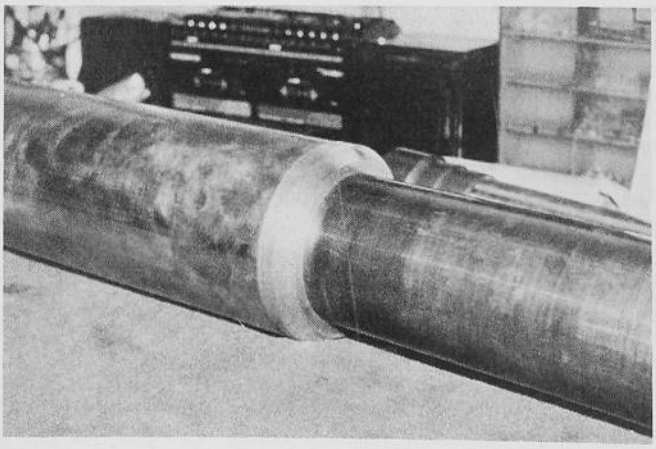
The declination axis and polar housing began life as cylinders of aluminum. In juxtaposition, the unfinished parts start to look like a telescope.

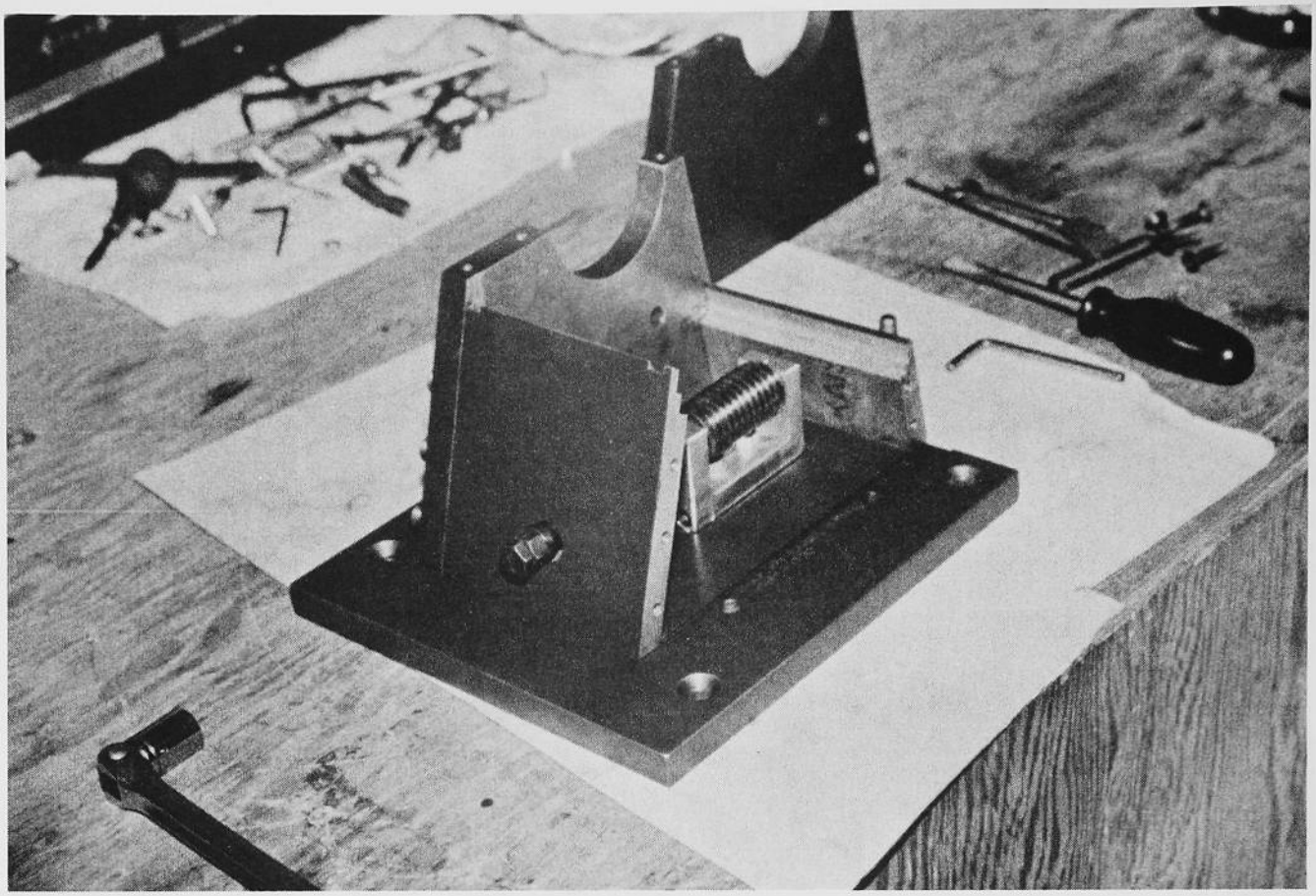


The neck in the tube began as flat disks. After turning it to diameter, Larry milled a ring of holes and removed the center. The pieces went back on the lathe and mill. These parts join two sections of the main tube.

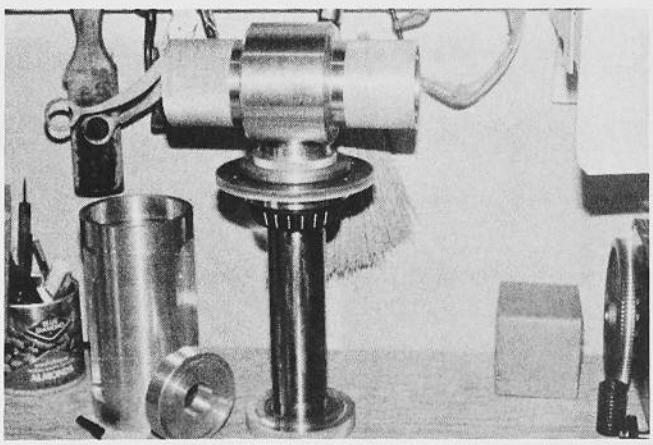


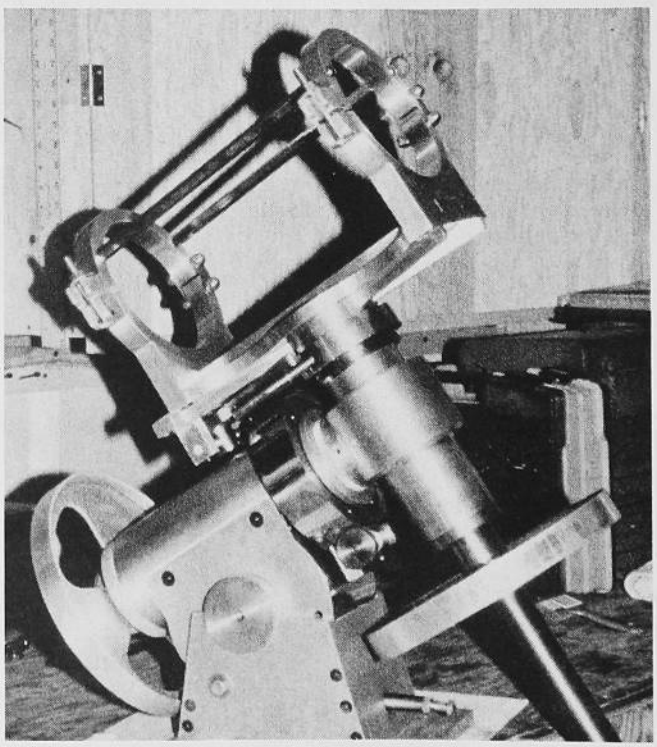


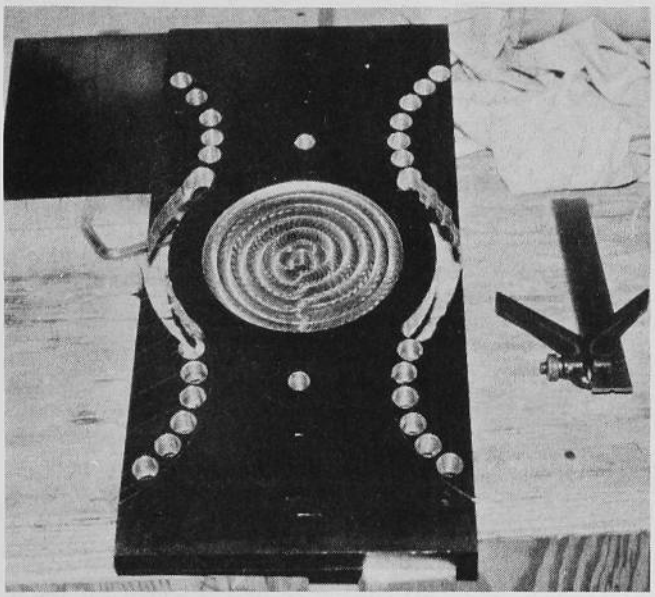


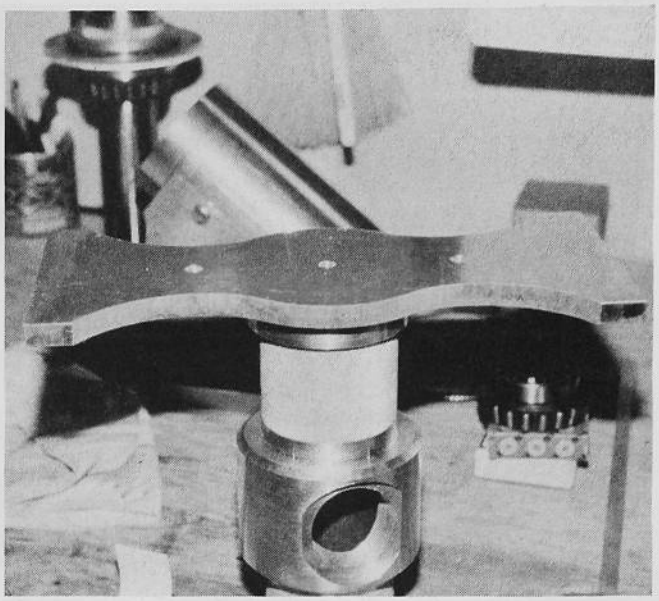


Here's the mounting again, literally built from the ground up. The worm gear allows fine control of polar angle. Large bearings in the polar axis provide solid support for the long and heavy instrument they will carry.

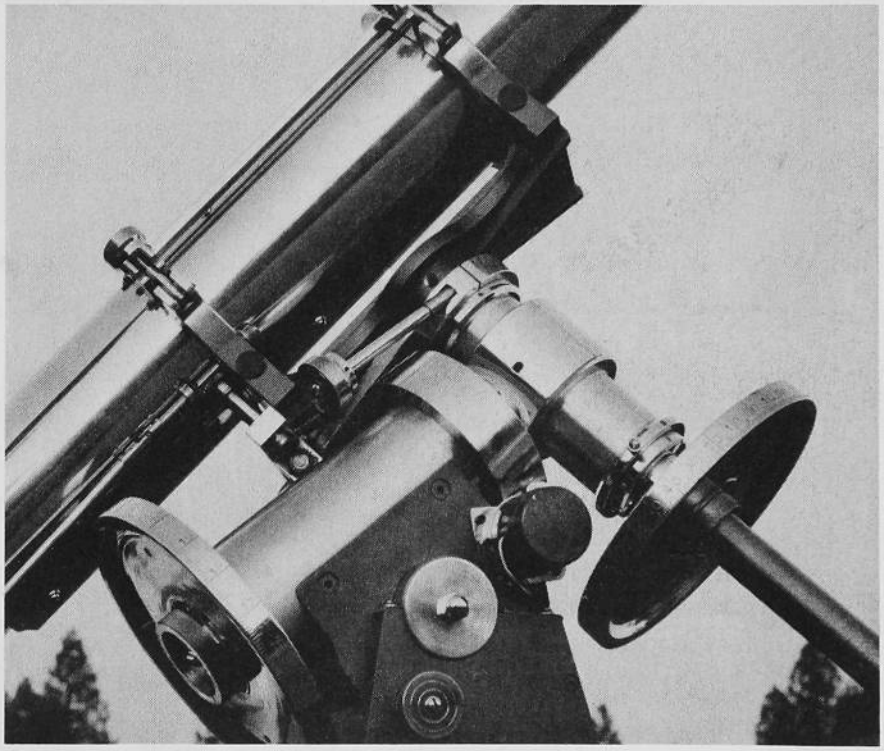








The saddle joins the telescope to the declination shaft of the mounting; it was formed by drilling, cutting, milling, and welding webs to the plate.



The completed mounting is a complex assembly of parts: the saddle, setting circles, motor drive, clamps, gears, bearings all working together.

"chicken or the egg" question would plague me throughout the project.

Rather early on, I decided to heed the advice Richard Berry gives in *Build Your Own Telescope* and check the quality of the objective. I assembled the rough tube, and in a very makeshift way, viewed my first object.

It's difficult to describe my utter disappointment. The view was terrible. After doing what I could with adjustments, I threw my hands up in complete disgust. The lens suffered a severe color problem.

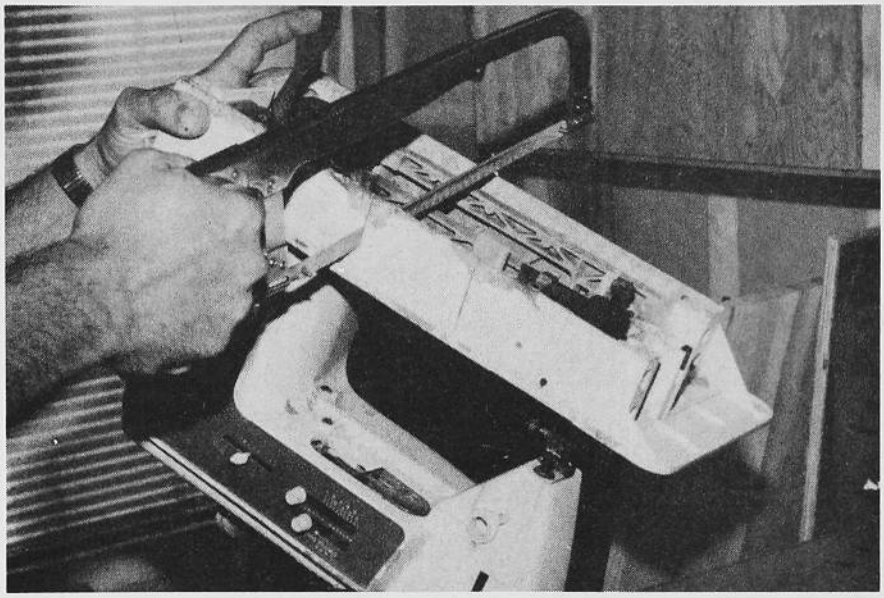
I now faced the decision of whether to continue the project or abandon it and go on to bigger and better things. Obviously I continued. I was soon on the phone with Barry Greiner at D&G Optical. I ordered a 6-inch f/15. I wanted a bit longer focal length since I now had a choice.

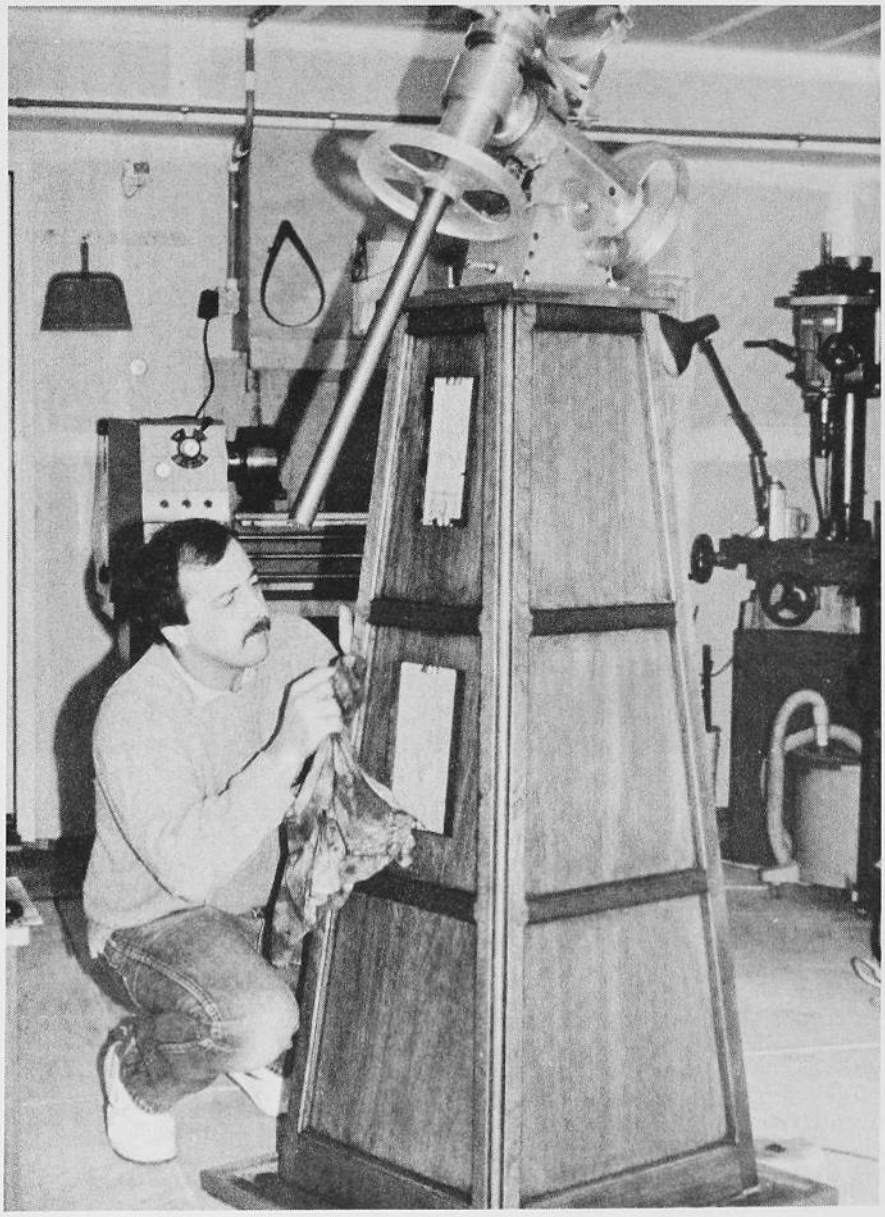
While awaiting the arrival of new objective, I had plenty of time to construct other parts of the scope. My friend Phil Mattingly (see his story on the Nightwatch Observatory in TM#37) designed a mahogany pier for me. Under his direction we spent the better part of two days on the rough construction of it. I then spent another three weeks on the finishing touches. Much to my surprise, a wooden pier is very sturdy!

I started the equatorial mounting early on. It was something I would work feverishly on for a couple of weeks and then put aside for a while. Never having practiced moderation, I would often find myself getting burned out and discouraged while building the mount. After a month or so I would then go back to it and start fresh, more often than not with new ideas.

Perhaps the best way to describe the equatorial mount is as follows: plate aluminum, aluminum tube, some stainless steel, lots of brass, a used Byers gear, a motor, and a few spare parts from an old Singer sewing machine. Originally, I had hoped to build everything myself without the aid of professional machine shops. Well, 99.9 percent of the mount was built in my garage, but I did have to rely on outside help a few times. Besides, you know what I think of my original plans.

Welding proved necessary, and I got that done outside. In my original plan, the polar shaft was threaded into the declination hous-





ing, but I found that unsuitable after the first assembly. Welding cured it. I also had the underside of the saddle assembly that holds the main tube welded. Welding made a substantial difference in the overall rigidity of the mounting.

The setting circles were a story within themselves. I had originally found a couple of aluminum wheels in a scrap yard. They seemed just perfect — or so I thought. I got them home and went straight to work on them. After I spent 50 hours working on them, I realized they were completely unusable. They were out of round and I was unable to true them on my lathe.

I then entered another world I was completely lost in: castings. I constructed a circular pattern from red oak. Many trips to the foundry in Lodi were necessary to get them right — and yes, I did feel like I was stuck in Lodi. After I finally received the castings the real work began.

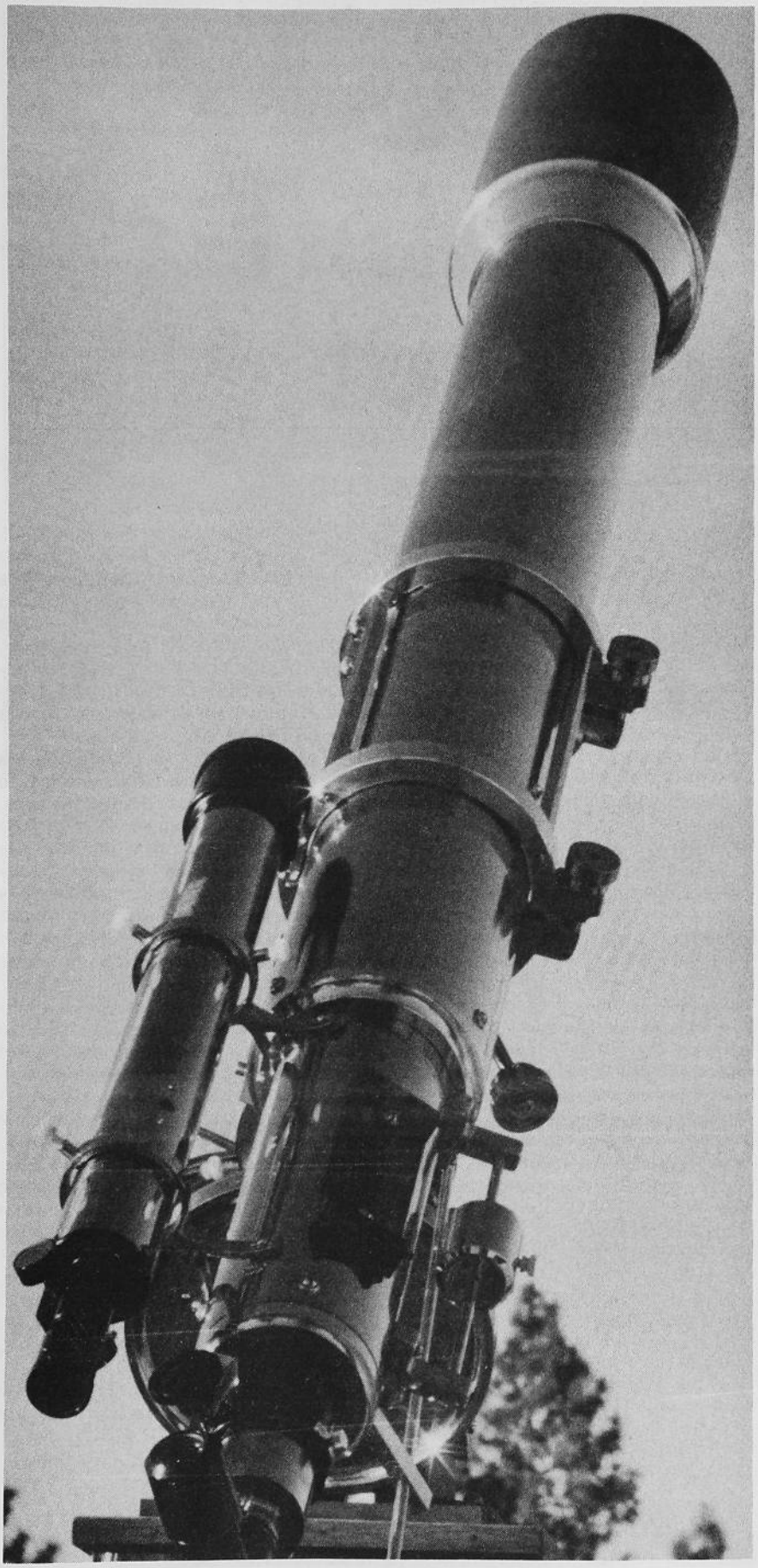
The work proceeded in steps. In step one I built tooling for mounting them on my lathe and rotary table. The second step was precisely tuning the wheels. Step three was indexing them with R.A. and declination lines. And the final step was brass plating. (In the end I had four parts brass plated: the two setting circles and the two finderscope brackets.) The result was two very accurate setting circles.

At present, two antique clock hands serve as pointers for the circles. I intend to make verniers for both circles in the near future. The R.A. circle is on a slip clutch and the declination circle is held in place by a large brass nut, so it can be set precisely. The pointer is also adjustable for easy reading, depending on the position of the mount.

Just as the setting circles turned out to be quite an involved project, so did the tangent arm assembly. I originally purchased four gears from a supply house, but they weren't quite what I wanted. The "simple" gear train I have now consists of four gears torn out of an old sewing machine.

Some people hang out in bars or malls, but I hang out in scrap yards. That's where I was, with gears on my mind, when I noticed an old decaying Singer lying in the mud. Upon closer inspection, I spied its gear

Rubbing on wood polish and cutting up an old sewing machine were parts of the same project: building a precise and beautiful refractor.



train. I knew right there on the spot they were what I needed. For a buck-and-a-half — a far cry from the $30 I had spent retail — I was in business. A two-foot stainless steel rod and a U-joint make for smooth declination movement.

Final Assembly

The time had finally arrived that I could start finishing touches. That included machining the end piece for a Unitron-type refractor focuser, mounting brackets, balancing everything, and an incredible amount of polishing! I have to admit that this stage of the project — when everything began to take shape — was my favorite. After 14 months of work and over 3,275 hours (I know: I kept a log book), I had doubts. But 95 percent of my doubts proved groundless — the 200+ parts fit together with hardly a hitch.

On October 27, 1990, I loaded everything into my pickup and drove to the Sacramento Club's site at Blue Canyon and set up. Anticipating problems, I think I also loaded most of my garage, just in case. I took a spare of everything, including the original objective! In retrospect, I have to laugh at myself. Through the course of the entire night, I believe I tightened only one bolt and replaced one Allen screw.

In a nutshell, I couldn't have been more pleased with the telescope's performance. The 2.75-inch polar shaft and 1.75-inch declination shaft provide an extremely steady platform. The telescope is well balanced, and it's almost effortless to move the 95-pound tube assembly. Although I didn't collimate the objective that night, it nevertheless provided outstanding images. I love seeing crisp stars to the edge of the field on a very dark background.

In conclusion, I can honestly say that this is the most ambitious project I've ever attempted. Was it worth it? You bet it was! In the not-so-distant future I'll start on the permanent housing for this and my other telescope.

I intend to use the refractor for visual and planetary photography and my C11 will be used mostly for deep-sky photography. Would I encourage others to try their hand at telescope making? Absolutely! Keeping in mind the patience required, the rewards can be unequalled.

Larry Myers
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Elk Grove, CA 95758

A New Apochromatic Doublet

The quest for the ultimate refractor is filled with frustration. The object of the quest seems simple: a lens that is free of chromatic aberration. Yet like the quest for the Holy Grail, this is seemingly impossible.

My quest for the ultimate refractor began shortly after Stellafane 1989. Using normal glass, I had already made a 4-inch refractor, an instrument that had won an award for optical quality. For my next project I wanted a larger instrument with better color correction, a 6-inch apochromat. I had experimented with the ray trace software from *Telescope Optics: Design and Evaluation* but I was unable to formulate a design with the desired performance.

Shortly thereafter I asked Harry McKinley, a friend and optical designer, for help in selecting a suitable glass combination to reduce the secondary spectrum that degrades the performance of all ordinary doublet objectives. Harry mentioned a new glass made by Ohara Glass which might be suitable for an apochromatic objective. After a few iterations with Harry's optical design software — software that automatically optimizes the optical system — we were looking at one of the finest designs for a doublet objective we had ever seen. Compared to 6-inch objectives with normal glasses (that typically have one full wave of color aberration using the d, F, and C wavelengths), the new design has greatly improved color correction.

According to Harry McKinley, the optical path difference (or OPD) method is a far better way to evaluate lens designs than the spot diagrams frequently used by telescope makers. The OPD method traces the path of light rays through the optical system and calculates the difference in their optical path lengths as they converge to the focus.

These results of an OPD calculation are displayed as a full "Y-fan" plot and a half "X-fan" in our case. The Y-fan plot are for rays traced in the plane of the drawing (as they would be drawn) and the X-fan plot is a trace of the rays out of the plane of the drawing across half the aperture. It's only necessary to show half the plot because the optic is symmetric in this plane. The aperture is normalized to ±1 wave of path difference on either side of the axis.

The new design takes the form of an f/15 Steinheil doublet using FKO3 and BK7 glasses. The BK7 is the element exposed to the air, and it protects the sensitive FKO3 from weathering. The fine performance of this new apochromat design comes at a price however. An Ohara FKO3 glass blank costs about $1200! The address of Ohara Glass is 50 Columbia Rd., Somerville, New Jersey 08876-3519, (201) 218-0100. BK7, a standard mass-produced glass of high quality, was considerably less expensive. I purchased a finished blank from United Lens of Southbridge, MA for under $100.

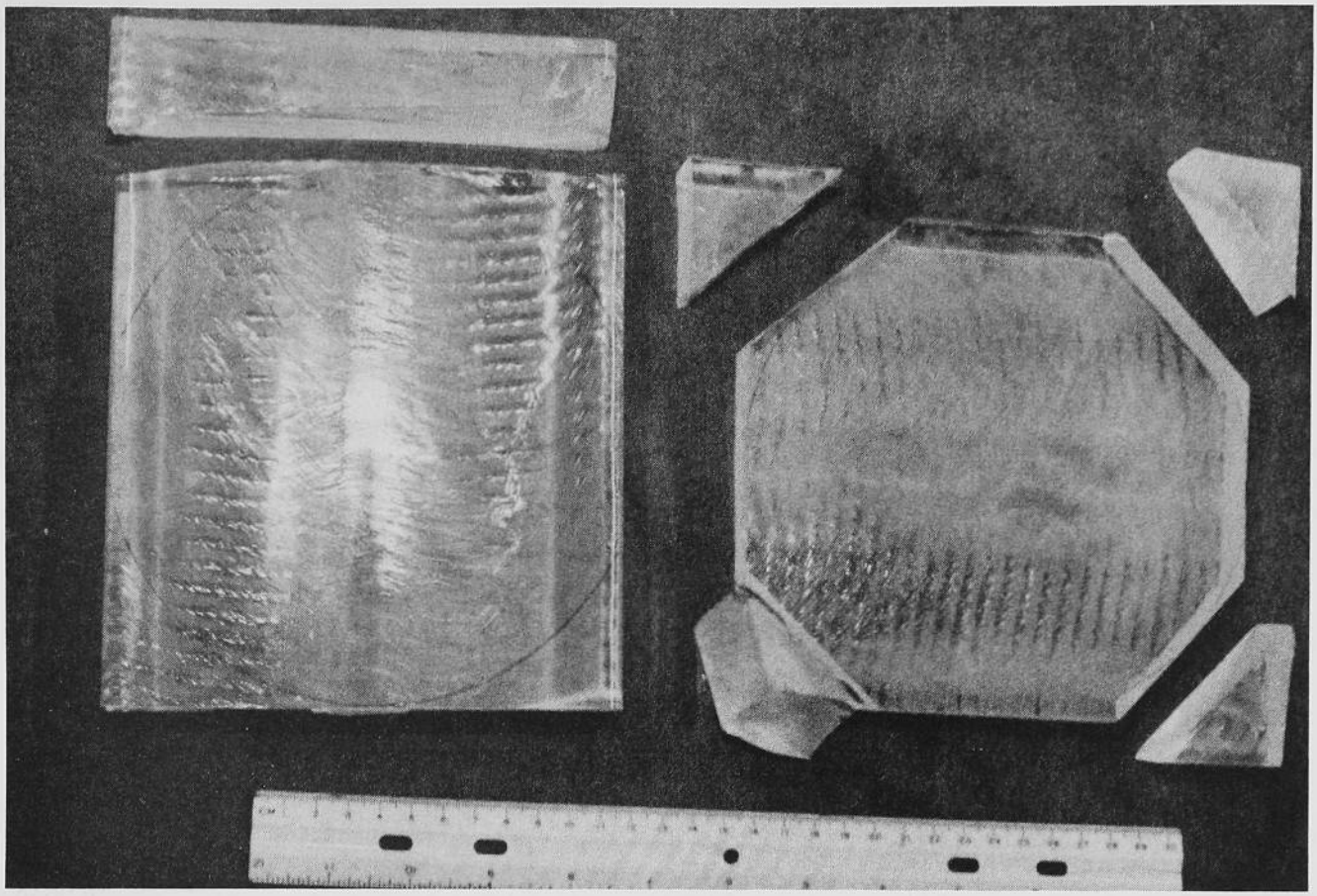
To preserve the fine chromatic correction of this apochromat, the original design must be modified to account for normal variations in glass characteristics. The catalog values of optical glass data, supplied by manufacturers and used by optical designers, are approximate values. For most optical systems, especially standard doublet objectives, the nominal values are sufficiently precise; normal variations in refractive index and dispersion have no practical effect on performance because there is a large amount of chromatic aberration anyway.

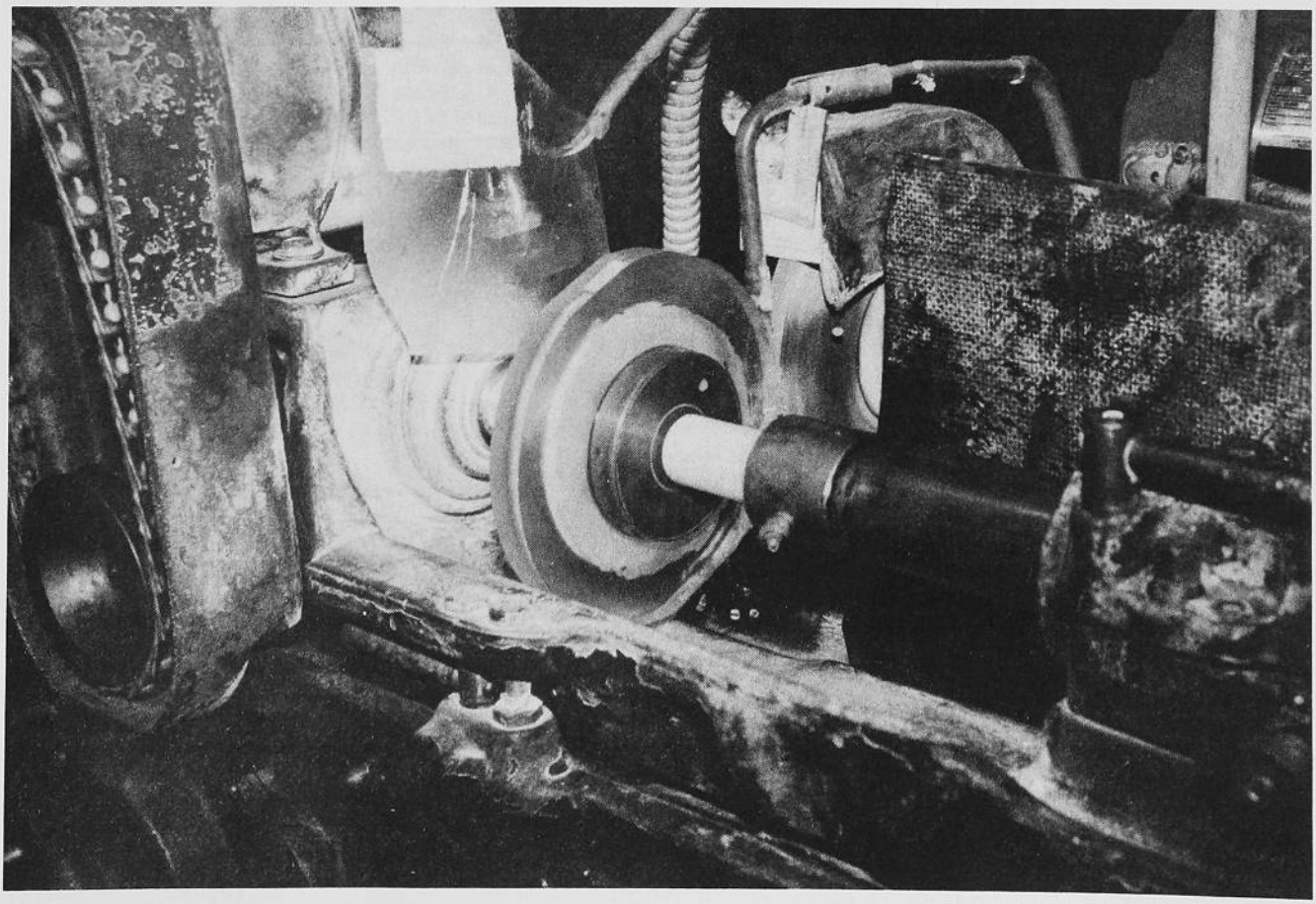
But for the highly optimized apochromat such is not the case. The normal variations in index can degrade an apochromat's performance to that of an ordinary doublet! Both the BK7 and FKO3 blanks differed enough from the published values to make a difference in the performance of the objective. After we received the actual blanks, Harry McKinley redesigned the lens around measured values. He shortened the focal length of the lens to f/13 and selected radii to match existing master test plates at work. The design published with this article uses catalog index values and works at f/15.

My project attracted the attention of my boss, Roland Leibmann, a master optician trained at Zeiss in Germany. He decided he wanted to build a telescope also, and so we ordered enough FKO3 for two telescopes from Ohara Glass in slab form.

In slab form, Ohara's FKO3 is available only in a 30-millimeter thickness. The optical shop where I work

Because we obtained our FKO3 glass in slab form, the first step was to prepare it for rounding by cutting it square and then cutting off corners. We rounded the blanks on a lathe against a diamond grinding wheel.





E.F.L. = 2045.6
B.F.L. = 2025.4

NOTES:
SURF #s LEFT to RIGHT
CX = CONVEX
CC = CONCAVE

SURF #	RADIUS	CNTR THK	GLASS
1	716.000 CX	13.000	BK7
2	294.974 CC	1.400	AIR
3	289.517 CX	15.000	FKO3
4	PLANO	2025.370	AIR

DIAMETER: 160.0
CLEAR AP: 156.0

DIMENSIONS IN MILLIMETERS

APOCHROMAT

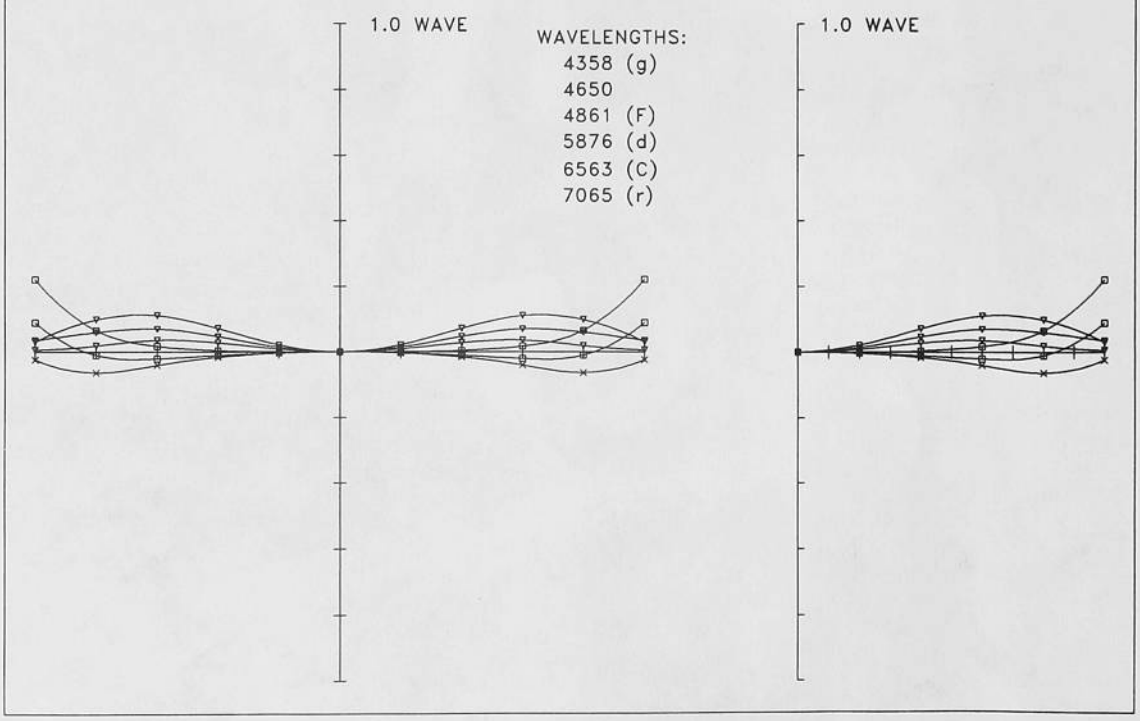
DWG. # 999

OCTOBER 11, 1990
SCALE: 0.50X

by McKINLEY OPTICS, Inc.

NEW APOCHROMAT
OPD CURVES

FOB 0
WV1..3: × ▽ □



The author roughs in a curve by hand on a rotating spindle. The FKO3 blanks had to be handled with extreme care; this material is sensitive to thermal shock, scratching, and chemical attack.

has the necessary equipment to shape the FKO3 into blanks for grinding and polishing, so we were able to order a slab. For an additional charge, TMs can purchase round blanks ready for grinding.

Making a lens element from FKO3 is a major job for an amateur. To begin, the standard amateur techniques for generating a curve do not work with FKO3 because FKO3 is very soft. FKO3 also scratches very easily, has a high coefficient of expansion, and may suffer from chemical attack. By contrast to the BK7 front element, which can be fabricated with the standard TM techniques, an FKO3 element demands special consideration.

We began work by sawing the slabs of FKO3 into squares. We ground the blanks round and diamond-generated them to the proper shape. But because FKO3 is very soft, you must leave a generous thickness for fine grinding.

Because the glass is so soft, the convex surface of the FKO3 lens blank must be ground in with a preformed tool. I think that you would probably grind the whole FKO3 blank away before the tool would acquire the correct curve if you were to use conventional amateur grinding techniques. The tool can be an old, chipped Pyrex mirror blank. It should be reconditioned against its mate after the curve has been rough ground into the FKO3 blank.

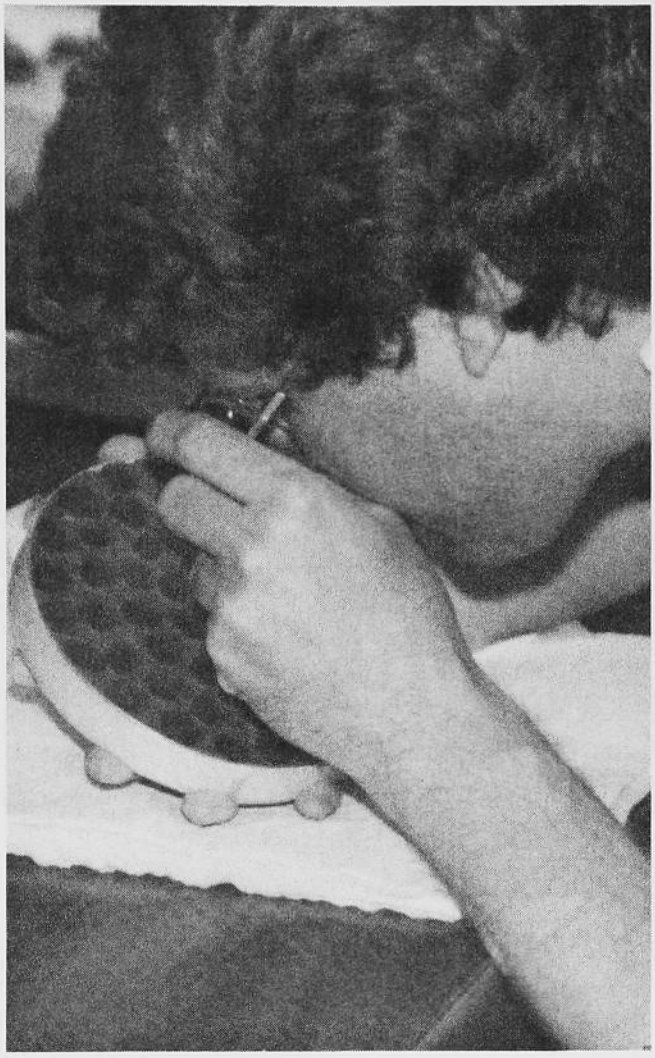
We ground the surfaces against preformed iron tools with the correct radius on a rotating spindle with the lens held by hand. During grinding we monitored the lens thickness very carefully, and any wedge in the glass was ground out.

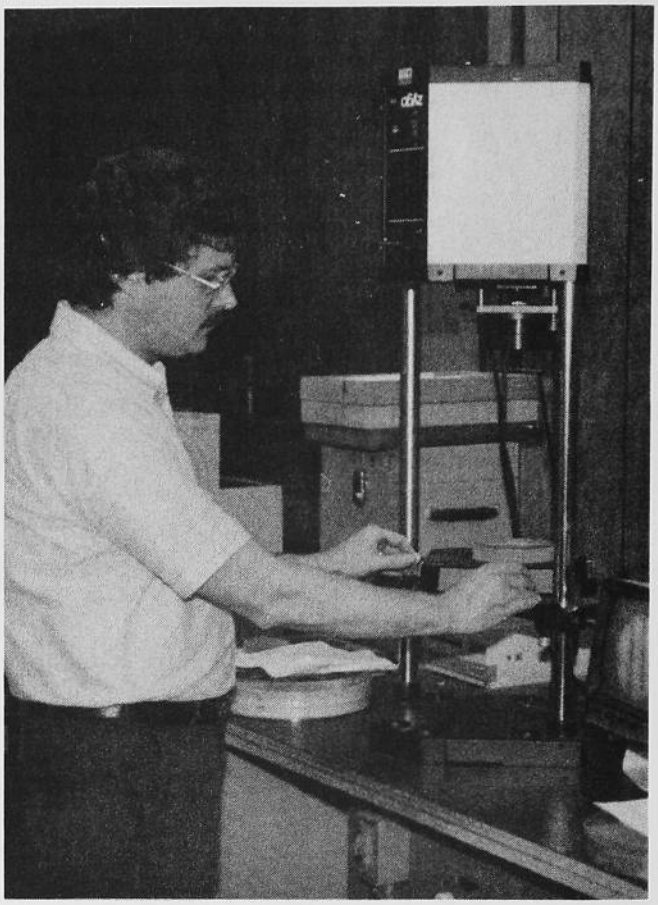
FKO3 is also very prone to scratching and must be handled with extreme care because you can almost scratch it with your fingernail! The glass grinds so fast that you can start with 40 micron grit. In the finer stages of fine grinding, a faceted tool is a must. It will help avoid scratching and sticking which will surely cause a disaster.

Another critical consideration when working FKO3 is this material's high coefficient of expansion. This creates the danger of thermal shock. A disk of FKO3 may fracture if the lens, after being warmed by handling during grinding or polishing, is doused in cold water or held under the tap to wash off abrasive. Hot-pressing the lap with the lens is also very hazardous. When working with ultra-sensitive glasses like FKO3, you have to treat them as if they might crack and fall apart in your hands at any moment!

We polished the surfaces with a medium-soft pitch on an overarm-style polishing machine. The radii were checked with test plates calibrated to within a ten-thousandth of an inch in radius using a spherometer we built in-house. (The lens radii are critical, especially the inner surfaces, and require an accurate spherometer to fabricate properly.) The master spherical test plates allowed us to use interferometry to determine surface accuracy to a high degree (see *TM#3*) of precision. A Zygo interferometer was also used to check the figure during the polishing and figuring stages.

In order to grind and polish the lenses by machine, we mounted them on tools that fit the rotating spindle





Above: The author checks the condition of the lap during polishing. Soft pitch was used to polish the FKO3 glass to miminize scratching and sleeking. In the final stages of polishing, the author maintained tight control of the radii by checking the surface against master radius plates. Right: Beside the finished telescope stands the author (left), an onlooker (center), and the author's colleague Roland Leibmann (right). The 6-inch f/13 objective is made with FKO3 and BK7 glasses. Mr. Leibmann also made one of these highly corrected objectives.

on the machine. Care must be taken not to distort the blank while it is being held in place because astigmatism will be the inevitable result.

Most TMs will do best to work the lens by hand, unmounted, and with the back surface protected from marring or scratching (see *TM#41*, page 5 for more lens working ideas).

Reflector owners know the damage that condensation and water droplets can do to an aluminized surface. The same is true of an uncoated apochromatic objective. The FKO3 element is especially vulnerable since this glass is easily stained and prone to oxidation. The bare glass surfaces also cause annoying and contrast-reducing ghost images, especially from the flat back surface. The lenses of this objective were coated with a highly efficient multi-layer, broad-band anti-reflection coating that reflects only 0.25% of the incident light per surface, about ten times better than a single layer of magnesium fluoride that is normally used for lens surfaces.

The lenses were coated by Optical Coating Technologies of Easthampton, MA. The president, Larry Songer, designed the coatings for the glass types in our objective and was very careful to protect the FKO3 from thermal shock. The coating charge was $800.00 for the set. Be sure to get in touch with Larry before you order your glass to see if he has the tooling for the diameter of your lenses. It is standard practice in the optical industry that the coating work be performed at the customer's risk. This means that if the coating house accidentally drops your $1200 lens element made of FKO3, the lens that you labored for months to complete, they are not liable!

The lens cell and back plate were fashioned from aluminum that I bought from a metal salvage company, and the tube was bought from an advertiser in TM. The cell was made 0.01 millimeters larger in diameter than the lens. Because aluminum contracts as it cools in cold weather, a too-tight cell could contract and pinch the lenses, causing distorted star images. Although we made no special allowances for the differences in expansion rates for BK7 and FKO3, we have not noticed any degradation in performance in 35-degree-Fahrenheit weather.

The finished lens elements were assembled into the cell a few days before Stellafane, but we had only about fifteen minutes of viewing that night before clouds moved in and prevented us from critically assessing the performance of our telescope.

The next observing opportunity was the night of

optical judging at Stellafane. We noticed some irregularity in the star images that night, but decided to enter the telescope in the optical quality competition anyway. (The judges were aware that Roland and I were professional opticians.) One of the judges asked if we had a "white filter" in our telescope, and another commented that "it's like looking through a reflector without the central obstruction." There was no hint of color even out of focus and the contrast was superb. We were delighted when we tied for first prize with a 12.5-inch f/6 reflector.

Later investigation revealed that the aluminum tube was out of round, stressing the cell and lenses enough to distort the star images slightly. Rounding the tube relieved the strain and fixed the star images.

I would like to thank Harry McKinley for the invaluable design work and Roland Leibmann for helping to make a challenging optical project a success.

Robert B. Douglas
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Southhampton, MA 01073

Editor's Note: Normally we encourage our readers to try their hand at fabricating the optics of a new design. However, I think TMs should think twice before attempting to tackle a project that involves expensive and fragile optical materials like FKO3. I am not one to cry over broken Pyrex, but a fractured FKO3 lens is a $1,200 heart breaker! To those who ignore this advice, good luck and tell us how the project goes.

—Peter Ceravolo

Building a Light-weight 30-inch Dobsonian

Bob Cox once told us that using one of our telescopes requires two things: a parachute, and an insurance policy against falling off high ladders. The telescopes keep getting larger, and the jokes still flow every time we take our telescopes out. The chatter goes on until those who have chattered reach the eyepiece, and then...it gets quiet.

A few years back Jeannie and I drove several hundred miles for a chance to look through a 24-inch f/6 telescope. After a wonderful observing session, we helped the owner dismantle the telescope and put it away. Although four of us were carrying it, each corner of the mirror box must have weighed a hundred pounds! The rest of the telescope was broken into several pieces and carried on a huge trailer.

On the long drive home our spirits were chilly, as if they'd been doused with ice water. We knew there was no way that between the two of us we could handle a telescope that weighed 800 pounds.

In the years since, as we have designed and built many large telescopes, our thinking has focused on two main design requirements. First and foremost was to see how light we could build each scope without sacrificing utility and solidity. We discovered that building a lightweight and portable telescope is much harder than building one that is permanent, where weight is of no concern.

The second requirement has always been "Keep it Simple." The more complicated something is, the greater the chance that Murphy's Law will grab you, especially when you're brain-dead and trying to pack up to go home at 5:00 a.m. Furthermore, the more complicated your telescope, the more likely it is that it will break down while you are observing.

History

Our first attempt at building a large, ultra-lightweight telescope produced a 20-inch f/7 that weighed 115 pounds before the finders were mounted. It was a little too loose for our liking, but provided us with invaluable experience for future models. The second scope of this design produced a delightful 18-inch f/6 that weighed under 140 pounds and is still quite solid four years later. However, this telescope and its successors were basically rigid structures; they did not fold up.

When we considered what would be required to transport a 30-inch f/5, we saw that transporting the instrument was a problem. Any telescope as large as 30 inches would have to fold up or break down, as well as weigh very little.

Before the 30-inch, we had resisted the urge to design a folding telescope because we go observing often. We enjoy telescopes that set up almost instantly. We wanted to keep the set-up simple and not design one that would take twice the time and effort.

Truss Tube Design

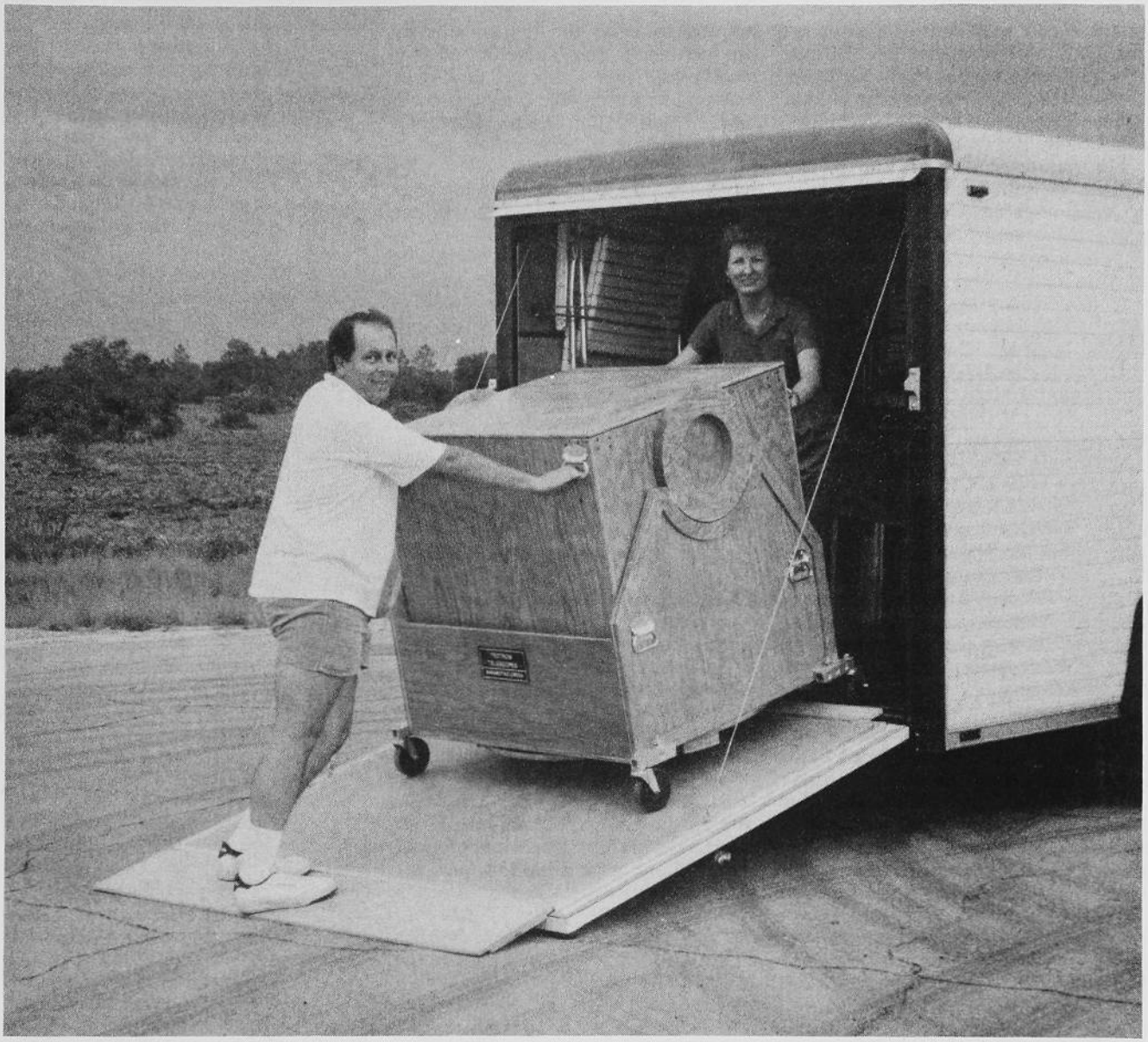
Eventually a tiny story by Ivar Hamberg on his folding 17-inch caught our eye (see *TM#17*, page 4). If Hamberg's design could be made quick and easy to assemble, then the instrument's compactness would be an attractive benefit.

Although there have been many other articles since on break-down telescopes, none had what we were looking for. Specifically, the truss tube mechanisms were either too difficult to make or did not look reliable, or we judged they would take too long to set up. What we needed was a clean sheet of paper on the old drawing board, a six-pack of Diet Coke, and a quiet evening when everyone had left for the day so there would be peace and quiet and time to think.

We were soon filling the trash can with designs too difficult to make or too costly to produce. Back to basics. The design had to hold the truss tubes in the proper place so that we could assemble the telescope without needing eight arms or three helpers. We ruled out climbing a ladder to assemble the diagonal cage in the dark; a 30-inch diagonal cage is too bulky for one person to handle.

As we converged on a solution, we decided the simplest way to clamp something is the old split block arrangement. Plenty of clamping pressure is available with a light twist of a large knurled knob. What we were after was to be able to set the poles in place and then tilt the telescope over so we could bolt on the diagonal cage while standing comfortably on the ground. We wanted the truss tubes sitting obediently in just the right place.

The clamping blocks we designed have a small stop on the bottom so the truss tubes do not go all the way through. As an added benefit, if the tubes are all the same length they will be interchangeable. At the



Tom and Jeannie Clark unload their 30-inch Dobsonian from its trailer. All parts except the strut tubes are carried inside the large box.

top of the scope a small piece of aluminum angle is mounted in four places. Each bracket has two hardened, socket-head screws mounted from the inside of the tube, protruding outward to form a stud. The top of each truss tube is flattened and has a hole that just slips over the mounting stud. The same type of knurled knobs used on the clamp blocks are used to tighten the truss tubes in place.

How to set the exact angles correctly was the only difficult problem left to overcome. Finally, the answer came jumping out of the blue. Each clamp block has two bolts holding it in place, right? Well, if just one bolt were put into place and left just a little loose, the block would be free to swivel on its own. So we could assemble the telescope with one screw in each block, and the angles would line themselves up. Gosh, how simple can you get?

When we place the clamps, we drill the first eight holes 1.5 inches from the top of the rocker box and 1.5 inches from the nearest edge. As long as we put these holes accurately in place, the interchangeability of the truss tubes is assured.

After the telescope is assembled, simply transfer the other bolt hole right in place. Because the bolt holes are tapped 10-32, we use a #21 drill to drill right through the tapped hole and through the wood. Then all you have to do is countersink the outside of the mirror box and run the bolts right though the wood and into the clamp block. On paper at least, this looked like a perfect alignment. Time to try it out.

We built a 14-incher to test some of these untried ideas. (See S&T, June 1990, page 665). This telescope was quite successful and was much more solid than we ever dreamed it would be. Vibrations from hitting the diagonal cage die away in about one second. One night we observed all night and didn't discover until we started to take the scope apart that we had forgotten to tighten the clamp blocks.

Construction Ideas

The biggest difference between this new design and other tele-

scopes we've seen is that the diagonal cage stores inside the mirror box. After all, if you are going to go to the trouble to take the scope apart to make it transport and store easier, why not be efficient?

The mirror sits on its cell in the bottom of the box. Just one inch above the mirror is a board that supports the mirror cover. Triangular supports are mounted in the corners for this board to be screwed to. That way it's removable for when you need to take out the mirror for cleaning or coating. The mirror box is then made just large enough to hold the diagonal cage. This placed our entire 14-inch telescope, except for the truss tubes, in a 22-inch cube.

With only a few changes from the prototype, the 30-inch was built. The main difference in construction is that when you sit down to sketch your plans for this design, you have to draw the diagonal cage first. Because it must fit inside the mirror box, the diagonal cage determines the size of the mirror box and that in turn determines the size of the rocker box.

Since we had always used Sonotube before, we found an unexpected side benefit from this new design. You can now build the tube any size you want it. For those who have followed our articles on optimizing Newtonian telescope performance, (see "SuperTune Your Telescope," *TM#39*) this is great for helping to keep the distance from the center of the diagonal to the focal plane (the intercept distance) as short as possible.

The 30-inch has a tube diameter of 31.5 inches, a 1-inch-thick board for mounting the focuser, and a low-profile, rack-and-pinion focuser with a minimum height of 1.6 inches. Allowing for 1/8 of an inch inward travel on a TeleVue 15mm Widefield (this eyepiece focuses 1/8 of an inch farther in than any other TeleVue eyepiece) we arrive at an intercept distance of 18 inches. This allows us to use a 4-inch diagonal and still have 100-percent illumination over a circle 0.38 inches in diameter.

By the way, try the following formula for determining your diagonal size (from our fellow club member Mark Haff). It is very simple yet gives results very close to those given by the more complex formulas.

Diagonal size
= diameter of 100% illumination
+ (intercept/focal ratio)

Basic construction of the 30-inch holds no big secrets. Any type of hardwood plywood works well for telescope construction because hardwood plywood has a solid core with few voids. We like oak for its beautiful grain pattern when finished. During assembly we use lots of glue. A few finishing nails hold the assembly together until there is time to install plenty of wood screws.

All parts of the rocker box, mirror box, and ground board are single thickness 3/4-inch plywood. (Gasp! Horrors!) We tried double walls on a 25-incher one time, and went back to the single-wall base for the next scope we built. We feel the additional stiffness isn't worth the added weight, and sometimes you can't even feel any additional stiffness.

Now we use an additional 1/2-inch thick by 2-inch wide trim around the edges of the 25s and 30s. The stiffness of the side walls is quite good. Dampening time from a good solid "thunk" on the diagonal cage is 4 or 5 seconds on the 30-incher. More to the point, the dampening time from hand tracking or focusing is zero seconds. Frankly, we don't thunk very much while we're observing.

The ground board is single thickness because we mount the Teflon pads directly over the feet, so it really doesn't matter how thick or thin the ground board is. The board simply serves as a web to keep the telescope positioned over the feet.

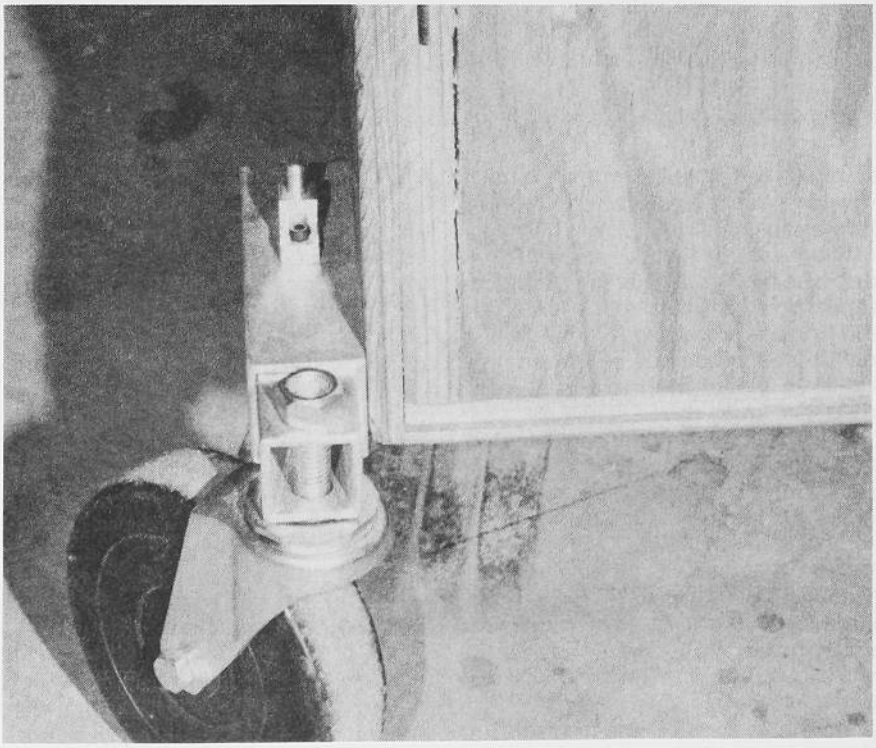
Everything you do on large telescopes is a compromise between weight and rigidity, and only experimentation will show what works the best. Even then, what works best for one design may not be optimum for another. The main thing we've learned so far is that a scope has to have some weight, but if it's a portable telescope, too much is worse than too little.

Weight and Balance

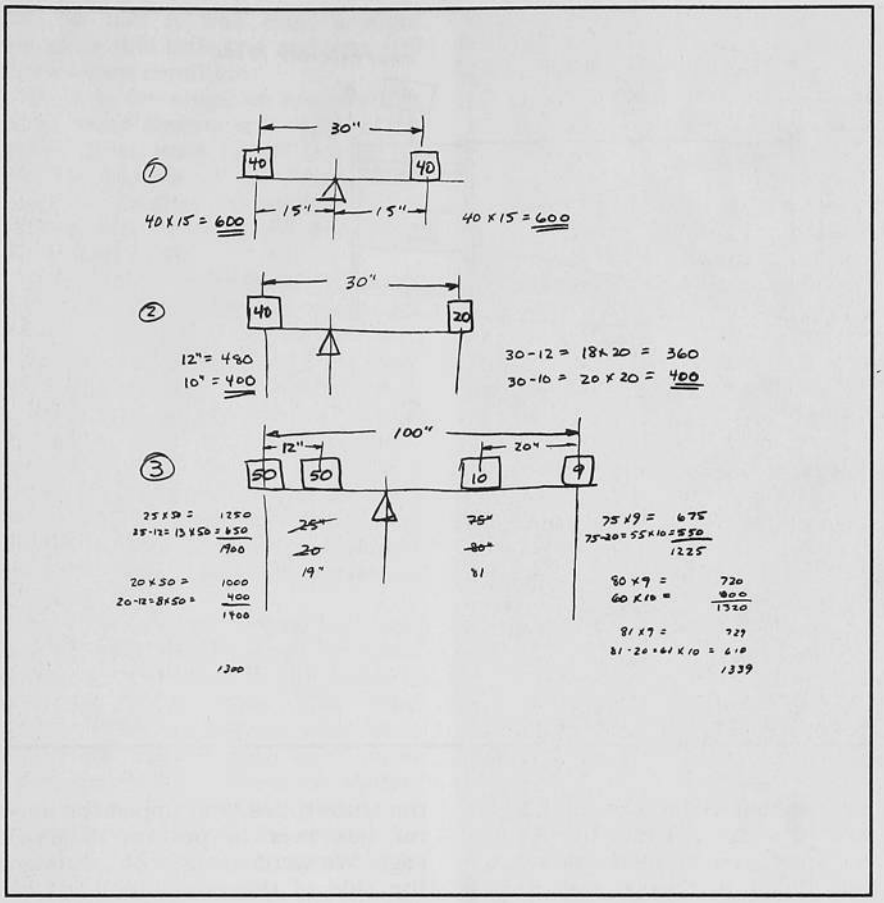
One thing is certain: adding weights to balance a telescope doesn't make it any lighter. Therefore, it would seem like the best thing to do would be to design the scope that is properly balanced in the first place, rather than "fixing" it later by adding weight.

You can do this two ways. The easiest way is to build your tube assembly complete with mirror, and then balance it on a broom handle on your work bench. Once you know where the balance point is, you build the rocker box to fit. This works great if you already have your mirror.

If you don't have your mirror yet, wouldn't you like to build the telescope and have everything ready for the mirror the day it arrives? Why



Crunch! On large telescopes, you may need a joint that's stronger than glue and screws provide. Aluminum angle now braces the corner.



wait months and then delay even longer while you build the scope?

If you would like to go observing the day your mirror arrives, you must calculate where your balance point will be on your telescope. You can then measure the parts to find just how high your rocker box will have to be. We used this method on the last eight telescopes we have designed, and the most we've had to move the altitude trunnions has been $^1/_2$ inch. Not bad!

Example 1: You have two 40-pound weights 30 inches apart. Want to guess where the balance point will be? Of course, it will be in the middle. To prove that the balance point is in the middle, multiply the numbers on the left by each other; then multiply the numbers on the right by each other. If the numbers match, you have the correct balance point. On the left you have 40 pounds times 15 inches, for 600 inch-pounds of torque. On the right you have 40 pounds times 15 inches, for 600 inch-pounds of torque. Since the two torques are equal, you have the correct answer.

Example 2: Now you have 40 pounds on the left and 20 pounds on the right. You know the two weights are 30 inches apart, but don't know where the balance point is. Let's guess at a starting point: 12 inches from the left. Multiply the left numbers and we have 40 pounds times 12 inches equals 480 inch-pounds. The right numbers are 30 minus 12 equals 18 inches, so 18 inches times 20 pounds equals 60 inch-pounds.

But the object is to get the answer on both sides to match. Since the torque on the left is 480 and the torque on the right is 360, you know the left is still heavier, so you pick new number that is smaller that 12. Try 10 inches. On the left you now have 10 inches times 40 pounds equals 400 inch-pounds. On the right you have 30 minus 10 equals 20, and 20 inches times 20 pounds equals 400 inch-pounds. Because you have a match, you know that the balance point is 10 inches from the 40-pound weight.

Example 3: The plot thickens. Now you have two weights on each side. We know what each weighs and how far apart each weight is, but need to find the balance point. Everything else is still the same. You just have to multiply two numbers on each side, add them together, and then compare them to the numbers on the other side. Easy!

Because the left-side weights are so much heavier, start by guessing the balance is 25 inches from the left. Write down 25 on the left side and 75 on the right side.

Left side:
25 x 50 = 1250
25 - 12 = 13 so 13 x 50 = 650
So the left total is: 1250 + 650 = 1900

Right side:
100 - 25 = 75 so 75 x 9 = 675
100 - 25 = 75 and 75 - 20 = 55, so 55 x 10 = 550
So the right side total is: 675 + 550 = 1200

Because 1900 is much larger than 1225, we know that we have to move much farther to the left. Trying 20 inches gives you 1400 and 1320. You're closer, so try again. Trying 19 inches gives 1300 and 1339, close enough for what you are trying to do.

If you have followed along with me this far, you are getting the idea. You can go into using decimals until you get an exact match, but it's not necessary.

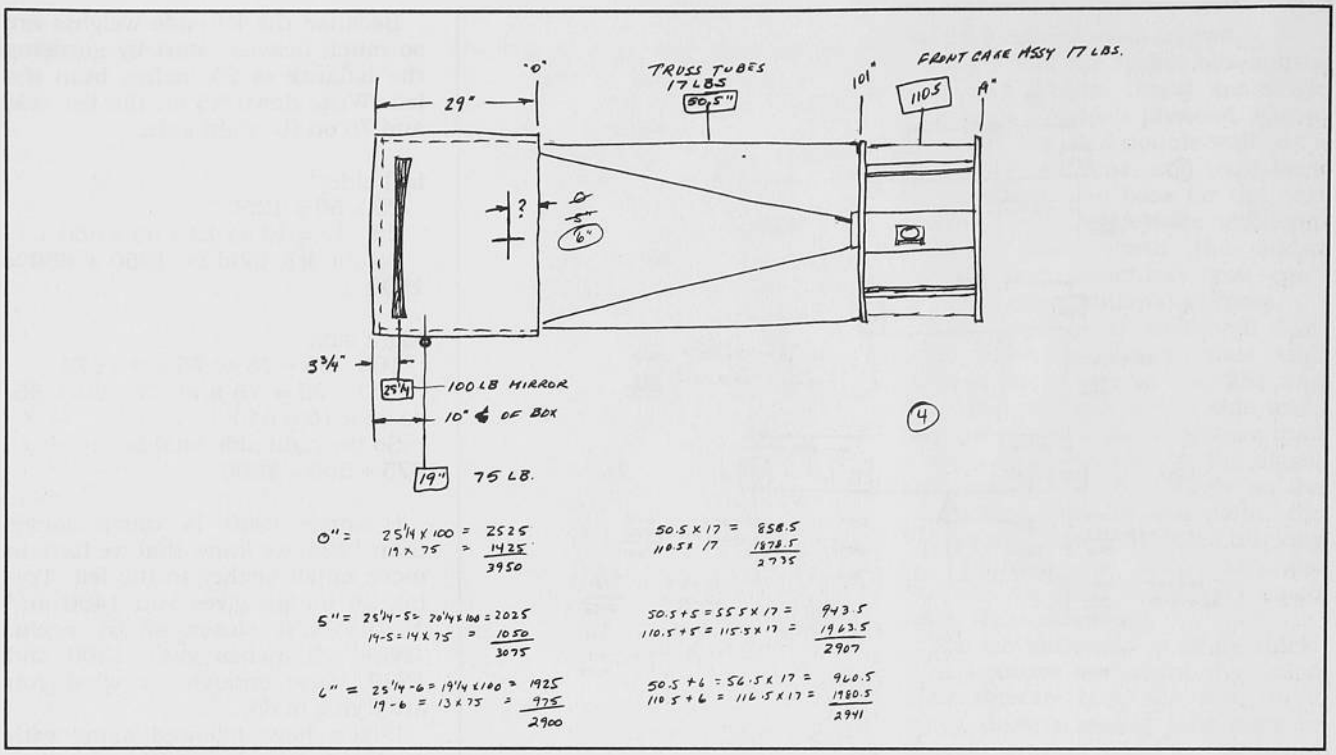
Example 4: This is the actual 30-inch telescope. The rocker box weighs 75 pounds. By using a broomstick handle to locate the center of gravity of the box, we found the balance to be 10 inches from the left end.

The optician told us the mirror would weigh about 100 pounds, and since we knew how high our mirror cell was, we determined that the center of the mirror would be 3.75 inches from the left end in our drawing. This gives us both weights for the left side of the problem.

The truss tubes weighs 17 pounds; there are 101 inches of open space between the mirror box and the diagonal cage. The trusses balance in the middle, so half of 101 inches gives a dimension of 50.5 inches from the starting point.

The cage assembly weighs out at 17 pounds, including the cage itself, diagonal, diagonal holder, spider, focuser, Telrad, and all the mounting hardware. The cage is 19 inches long and the weight is fairly uniformly distributed, so use 9.5 inches and add that to the 101-inch dimension. This gives a starting dimension of 110.5 inches as the center of gravity for the diagonal cage.

Using the four dimensions listed, you work the problem exactly as you did example 3. Using the zero point to start, you get 3950 on the



left and 2735 on the right. It's too heavy on the left.

Now try a balance point 5 inches to the left. Subtract 5 inches from the left dimensions and add 5 inches to the right dimensions. This gives 3075 for the left and 2907 for the right. Much closer.

When you set the balance point 6 inches to the left, you get 2900 and 2941, and that's close enough to build the scope. We actually built our first 30-inch to these dimensions, and by the time all the hundreds of details were finished, we only had to move the trunnions $^1/_2$ an inch to the left for a perfectly balanced telescope.

Optics

First light for all our telescopes is when we open the overhead door of our telescope shop and focus the scope on a star to locate the true focus of a mirror. We start with the truss tubes an inch too long so we can mount the focuser as low as possible. Simply remove the 1.25-inch adapter and lay an eyepiece inside the two-inch barrel of the focuser. (We use a TeleVue 24mm Widefield because its barrel is small enough to fit inside a 2-inch focuser tube but large enough to be nearly centered.) Slide the eyepiece down the focuser body until something comes into focus.

The day the 30-inch mirror arrived from Intermountain Optics, we dropped it (or should we say, "placed it gently") into the finished telescope, did a quick collimation, and rolled the scope over to the door so we could test it that evening as soon as darkness fell.

It was a murky evening with plenty of clouds, but pretty soon a star became visible not too high in the southeast. We located the star in the empty drawtube, and then slid the 24mm in until it started to focus. As the star started to come into focus, it seemed awfully fat.

We were just starting to think either the seeing was lousy or this mirror was — but snap judgements aren't worth much. When it focused, there was the most three-dimensional view of the most colorful image of Saturn that we had ever seen. Cassini's Division was crisp all the way around the planet. Wow! So much for the fears of just another light bucket.

Dark Skies

Many years after trying to order a Coulter 29, we finally had a finished 30-incher ready to go. Several quick phone calls later, we had a little first-light party planned at Florida's best dark-sky site, in deserted North Florida near Chiefland.

After setting up camp and greeting old friends who had traveled far to join us for this special weekend, we started setting up the scopes. We rolled out the 30-incher, seated the truss tubes, and tipped the mirror box over to put on diagonal cage. We were using a pin through the side of the boxes to hold the mirror box tipped for assembly, but for some reason the pin would not go in. The parts no longer lined up. Something was wrong! Disaster!

A joint in the rocker box had failed, and the rocker box was coming apart. Our good friend Ed Boutwell, with his never-ending good nature, assured us that everything was under control. He came waltzing up with his tool box and grinning broadly, pulled out the longest wood screws we had ever seen, and said we might mess up the pretty woodwork but he could get us through the weekend.

"To heck with the woodwork," we said. "Stick 'em in."

With the smaller telescopes of this design, one person can lift the mirror box, rotate it 90 degrees, and lower it to the bottom of the rocker box. This takes the pressure of traveling off the side walls of the rocker box and puts it on the bottom where everything is much more solid.

The 25- and 30-inchers can do the same thing, but it takes serious muscle power, more than Jeannie and Tom alone can provide. The solution is to simply leave the mirror box in place, riding on the side walls. This has been absolutely no problem for the 25-incher we've been using for the last six months,

and in fact it was even brought along on this little trip and was still in excellent condition.

Back in the shop, we removed the large wood screws and reglued the joints. Now, what to do? Double all the thicknesses of the wood parts and add another 10 pounds to the 102-pound rocker box? No! First think it through.

What failed? A six-inch long seam that was glued and had two small 2-inch long wood screws screwed into the end grain of the plywood. End-grain screws are weaker than screws that go through the grain sideways. How can we use side-grain screws for these joints? Use a piece of aluminum angle in each corner for extra strength. For a total weight penalty of perhaps a pound or two, these joints will cause no more trouble.

So why are we telling on ourselves? After all, our scope fell apart before we ever used it. Our belief is that by telling other TMs what doesn't work as well as what does work, we can all help each other learn. That's what *Telescope Making* does best — it lets us share our experiences with all the other telescope makers who are interested in the same things we are.

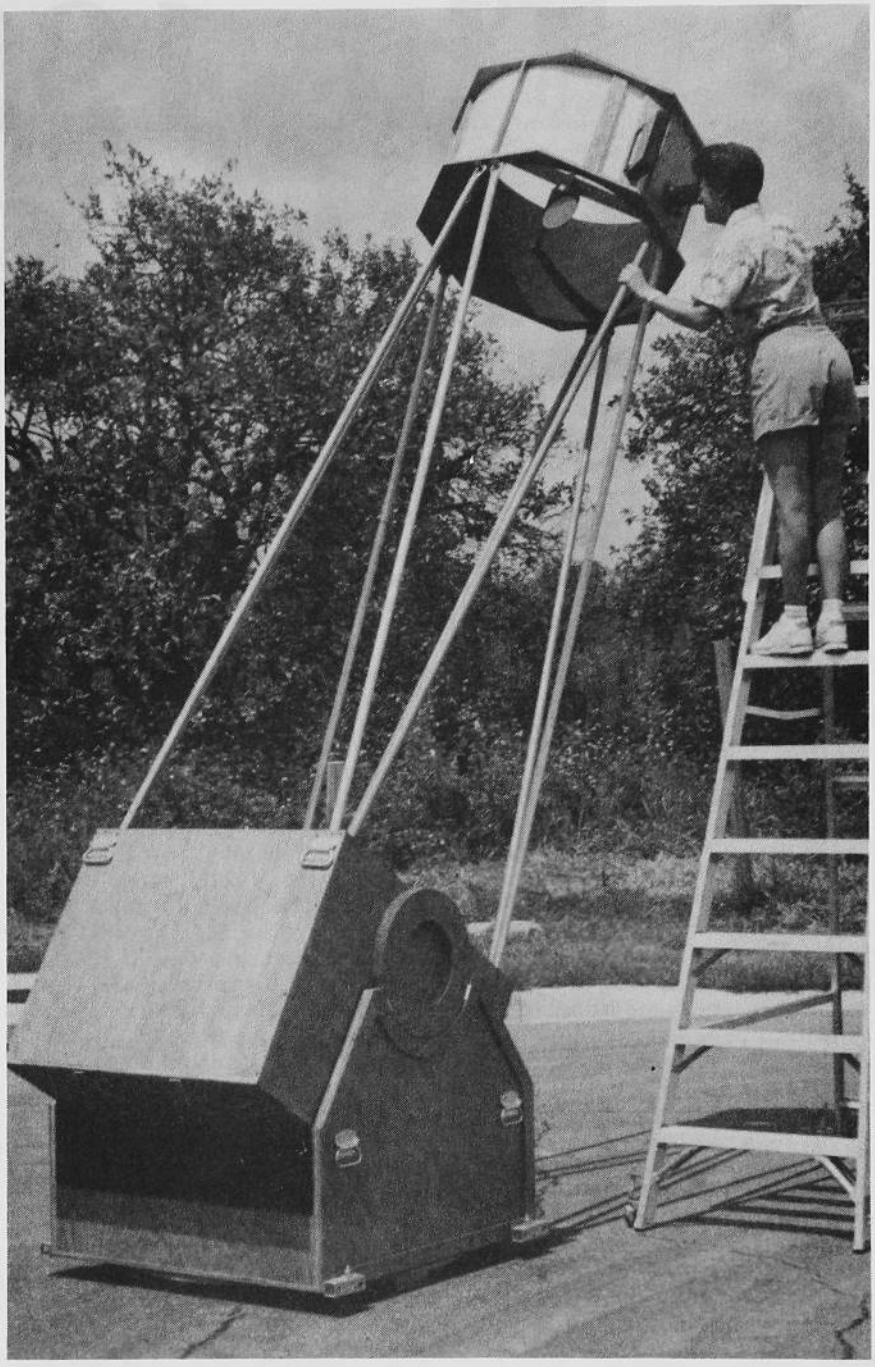
Finally!

Ok, enough of the story-telling. How does the telescope perform? Thanks to David Kriege's story in *TM#38* and Wilsonart 4552-50, our 350-pound monster has smooth and easy movements using plain, old Teflon and Formica (oops, we mean Wilsonart!) bearings. Even when it's pointed almost straight up, hand tracking is still easy. Of course, it's not as easy as our little 15-incher, but it's still well within the range most people consider manageable.

What images does a 30-inch f/5 provide? We have not yet had the scope finished long enough to tell the whole story. Our best observing weather is yet to come, but we can give a few hints of what we have seen so far.

Is it really a big jump from the 25? Yes. Is there a noticeable gain in resolution? Yes. Globular clusters are totally resolved, even little ones like M-80 become quite a sight. M-13 is a new universe that you can zoom in and out of while gently focusing back and forth. The effect is otherworldly.

The Veil shows so much more than you could see before that you have to wonder if it was there all the time. The Trifid no longer has three major dust lanes, but four. Maybe it should be called the Quadfid? And believe it or not, the Trifid shows color, a sort of green tinge with a little pink on the edge.



Halfway to the stars already, Jeannie Clark looks through the eyepiece of the 30-incher. Despite its size, the telescope is still easy to move.

Bright nebulae like the Orion Nebula fill the entire field of view. Observers with sensitive color vision even say they can see color.

Saturn is quite three-dimensional during periods of good seeing, and much more color shows up than we are used to seeing in that generally beige-toned planet. Comet Levy had a beautiful 1.5-degree tail last August 22. Way to go David!

The bottom line is that everything we look at is different than it used to be in the old 25-inch, and the excitement is renewed for the Nth time. Do we still want a larger scope after this? You bet!

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Sarasota, Florida 34243

The 1991 Winter Star Party

To winter-weary Wisconsin eyes, green is an unnatural color. White, of course, is the natural color, followed by gray, brown, and mungy shades of black. There are a few shades of tan visible in the natural world and microscopic bits of red (from the cardinals at the bird feeder) and a rare bit of blue (as in cold, steely blue sky).

Thus Florida comes as a bit of a shock. After months of sunlight deprivation, the sight of acres of green grass, the million living smells of summertime humidity, the delicious feel of wind on bare arms, the taste of ocean salt in the air, and the clattering sound the wind makes when it blows through palm fronds — ach — it's almost painful to write about a few weeks later.

This year I flew to Miami a day ahead of the Winter Star Party to spend a day and night with Don Parker. Don devotes himself to photographing planets, especially Mars, from a tiny observatory on the balcony of his house. His invitation had a familiar ring: Gee Richard, why don't you "come on down?"

I wanted to see Don in operation and help him get his newest camera on line. Those who follow *TM* closely may remember that when Don came to AstroFest last year, he and I had gotten engrossed in the "computer game" of image processing copies of Don negatives and color slides. This time we had the real thing in mind: digital images of the planets, fresh off the telescope.

Don lives in a rambling sort of house on a canal near the ocean, in Coral Gables, on the turn-around at the end of a dead-end street. His is "the house with all the cars parked in front," a description that fits. Not only does an exceptionally active family live in the house, but during the week before the Winter Star Party there's a regular procession of ALPO folks, friends, and journalists who were, like myself, visiting.

For example, in the side yard Jim Carroll was fussing with his new 18-inch NGT. The telescope was set up in the driveway, tipped to the unseemly latitude of Florida, and trailing cables and wires over to his van. There sat a huge TV monitor. Jim has equipped his NGT with an 18-inch f/6 mirror made by Dan Joyce and a compact video camera at the focus.

Jim and Dan had driven down from Chicago, and were in the process of sharing the flu. Dan had sneezed and wheezed for 1,500 road miles and was now getting over it; Jim was starting to come down with it. (Not to jump ahead of my story, but the frame-filling videos Jim would be shooting of Jupiter that night are absolute knock-outs.)

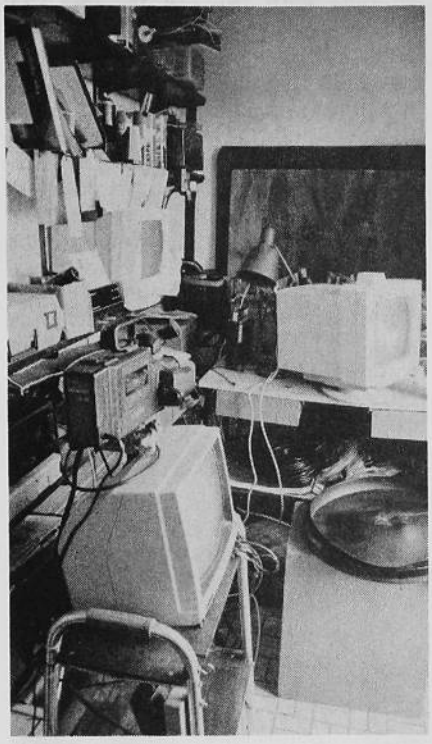
We spent the afternoon looking at some of Jim's old videos and chit-chatting about astrophotography and telescopes. Then I got the tour of Don's house. There's a machine shop in the garage and a video studio in the kitchen and...maybe I'd better explain. Maureen, Don's wife, is into video in a big way. She and Dan share this enthusiasm and were talking about white balance and other video stuff that afternoon.

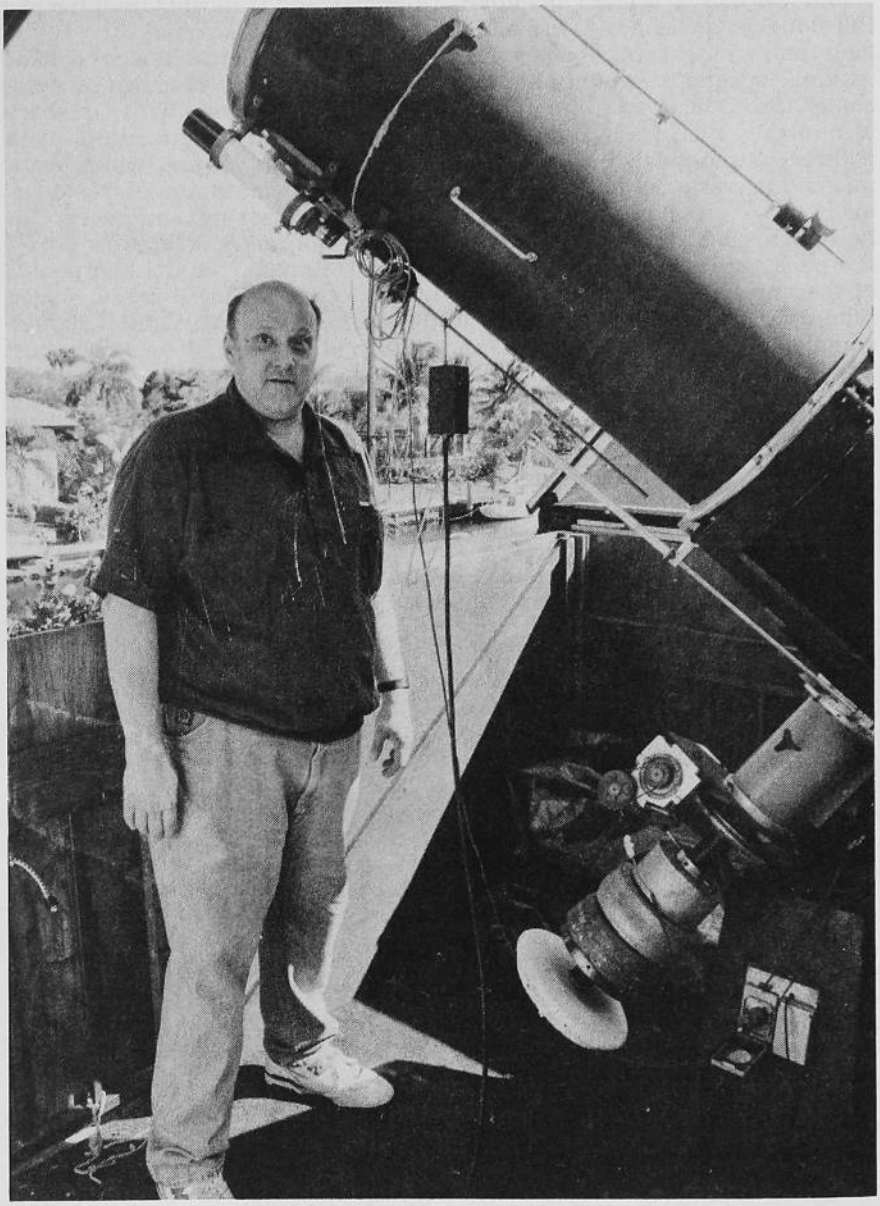
Upstairs, the master bedroom is full of computers and video gear. Just off the bedroom, Don has converted a closet into a darkroom and the room adjacent to that into a telescope ready-room packed with eyepiece cases, reference books, a clock-drive controller, and TV monitors. From the ready-room, double doors open to a second-floor porch that couldn't be over 10 feet square, and that's where Don keeps his telescope.

It's a tight fit. The telescope fits under a slide-off roof that opens when you open the doors and can be closed by closing the door. Various strategic notches in the woodwork of the house accommodate the swing radius of the 16-inch Newtonian, testimony to the negative clearances he found when he upgraded his old 12-inch.

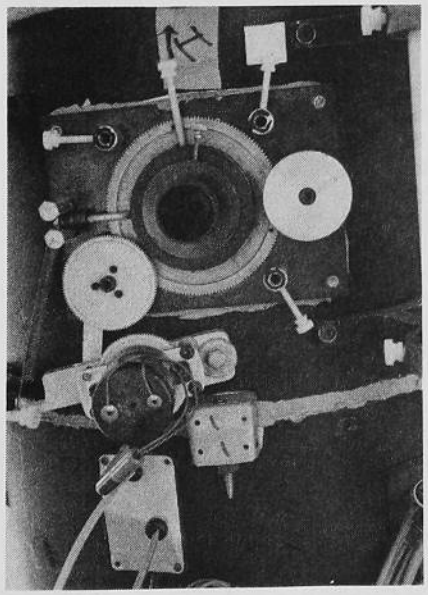
The 16-incher has a Dan Joyce mirror and clearly owes a lot to the machine shop in the garage. It's a great observing machine. With the help of slow-motion controls on both axes of his telescope, a motorized focuser, and his video camera or Lynxx CCD camera, Don's attained a key measure of astronomical professionalism: he can observe from a lighted room with his back to the telescope!

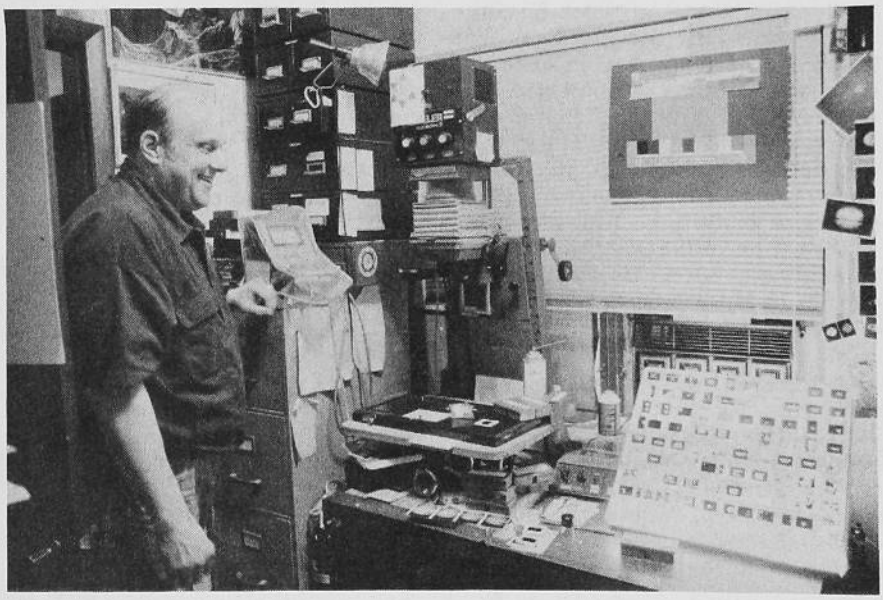
When we went downstairs, the house was in an uproar. Daughter Margaret was back from a game of high-school basketball (Maureen shoots videos of the games) and was bouncing around the house still high on adrenalin. Son Mike zoomed through on his way somewhere, and Fred, a humongous orange tabby, thought it was time for dinner. Jim and Dan were gearing up for an evening of shooting Jupiter videos with the NGT.





Good technique, steady Miami skies, and a handy large-aperture telescope have made Don Parker one of the world's leading planetary astrophotographers. Observing accessories (now including both video and computer monitors) are ready for use just a few steps away from the telescope, and a fully-equipped darkroom is close at hand. Don's telescope has motorized focusing (see below) so that heat from the observer's body does not interfere with the fine seeing at his home. The air is steady because Don lives only two blocks from the Atlantic Ocean.





And we had a dinner invitation. Bill Douglas, a friend of Don's and a long-time amateur astronomer, was making spaghetti and would we come? So Don, Dan, Jim, and I went over to Bill's place and enjoyed a three-course meal. Bill had been machining parts in his garage for an H-alpha refractor that day, and he has a roll-off roof observatory in the back yard. He showed us some of the surplus goodies he's latched onto at scrap prices — including a complete research-grade spectrophotometer from the mid-60s. (P.S. Thanks again for dinner, Bill!) We invited Bill to come back and shoot Jupiter, but it was getting late.

Back at Don's place, Don and I set up the Lynxx while Jim and Dan set up the video camera on the NGT. Don and I were using the Lynxx with eyepiece projection, and we had to get the scale right. (Don had some great shots from the week before, but the image scale was a bit too small.) So he tried several different eyepieces until he found one that gave a Jupiter images that spanned about 85 percent of the frame. A focal ratio around f/25 allows cameras like the Lynxx to record diffraction-limited detail, and on Don's 16-inch telescope, the scale works out to 4 pixels per arc-second!

To my surprise, Don got away with putting 20-foot extension cables on his keyboard and monitor so we observed from the ready-room using a "remote" computer located in the bedroom. We made a good team — Don kept the telescope on target and focused perfectly while I ran the camera and snapped off images. We found that exposures between 0.1 and 0.25 seconds produced images with pixel values of 3,000 (i.e., fully exposed) in the center of the Jovian disk. (For comparison, Don uses 2-second exposures for Jupiter photography.)

Time flew by. By 2:30, when Jupiter started to crawl over the roof line, we had 98 images in the computer. We shot a lot more, it's just that we didn't keep more than every third one we shot. As we got better pictures, we got fussier about what we'd keep. Among the images was a sixteen-frame "movie" showing the Great Red Spot rotating onto the disk and Io moving from the sky to the limb of the planet.

Although the raw images looked pretty good, a bit of image processing did wonders. With unsharp masking and sharpening, out "popped" belts, zones, white ovals, and rows of equatorial festoons. Unsharp masking enhances the contrast of image structures 3 to 5 pixels across, and sharpening enhances pixel-level detail. When we turned in that night, I figured Don had just shot some of the best still frames of Jupiter ever done on amateur equipment.

Meanwhile, down in the driveway beside the house, Jim and Don were taping Jupiter with the NGT. In their tapes, Jupiter filled a least half the frame — a truly heroic scale — and you could see more on the TV screen than you could visually with the same telescope. In moments of good seeing the eye discerns incredible detail, but it's fleeting. With the CCD, you freeze a single frame and then massage it until you can see every-thing there is to see in it. Both systems appear to be limited by the diffraction in the optical system.

The difference is this: with the video camera, you examine 30 rather noisy frames per second and let your eye integrate the noise, whereas with the still-frame CCD, you expose a single frame with a small number of pixels, but with very high signal-to-noise ratio. Both techniques record about the same ultimate detail, but in quite different ways. The night was a great revelation and a wonderful way to start the 1991 Winter Star Party.

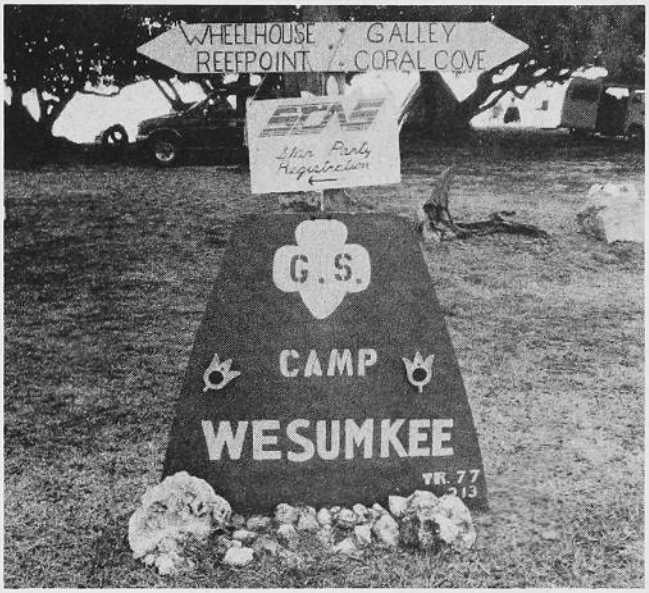
The next morning, after muffins and coffee at a local restaurant, I headed for the Keys. In previous years, the Winter Star Party has been held at Camp Sawyer on West Summerland Key, which is about 30 miles short of Key West. However, the Boy Scout reneged on their promise, and two weeks before the meeting, canceled out. However, the Girl Scout Council made Camp Wesumkee (wih-ZOOM-key), a property adjoining Camp Sawyer, available to the Star Party.

The Boy Scouts' unexplained and unwarranted last-minute cancellation left a bit of a bad taste in my mouth and greatly inconvenienced the members of the Southern Cross Astronomical Society who organized the Star Party. After accepting an advance payment, there's no excuse for suddenly closing the camp. Nonetheless, the organizers brought off a fine meeting at Camp Wesumkee.

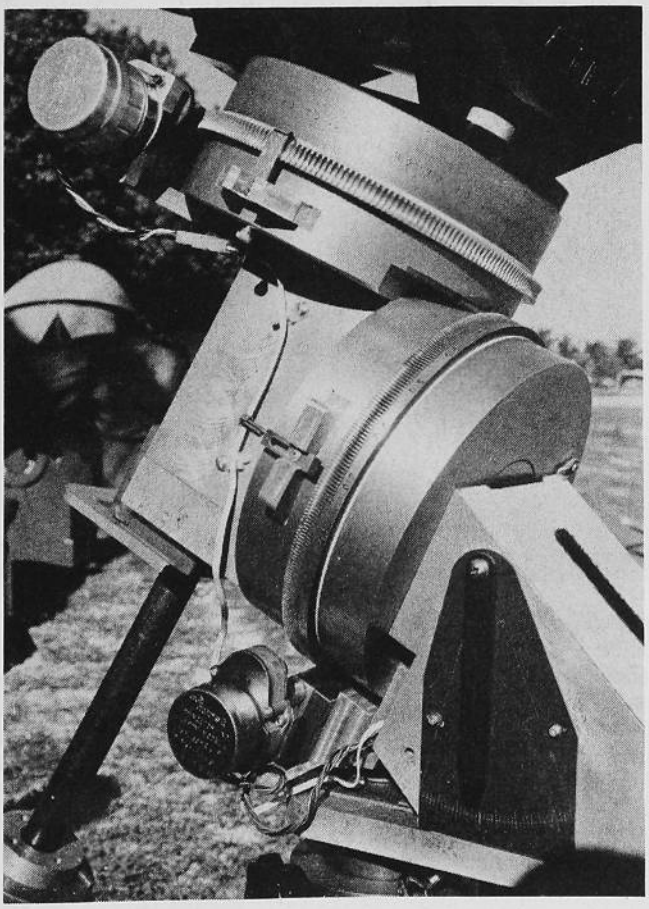
Actually, I liked Camp Wesumkee a lot more because the washrooms had luke-warm showers (not hot, but Sawyer has cooold showers). They also had ample toilet facilities for women, which Sawyer lacks. With an record attendance of 520 people, such considerations are crucial.

As I have in the past, I planned to camp at the Winter Star Party, but this year, I had a new tent, a 2-person dome tent. (Old Faithful, the Egyptian cotton pup tent Ele and I have used for 25 years, succumbed to Continental Airlines' baggage handlers on the return trip from last year's WSP.) At any rate, as soon as I pulled into Camp Wesumkee, registered, and started to reconnoiter — I was swept up in the whirl of Tippy and Pat D'Auria going to dinner. We popped the tent up (it was new; I'd never set it up before!) and off we went. That night was pretty much cloudy and I was tired from shooting Jupiter pictures, so after dinner I called it a day.

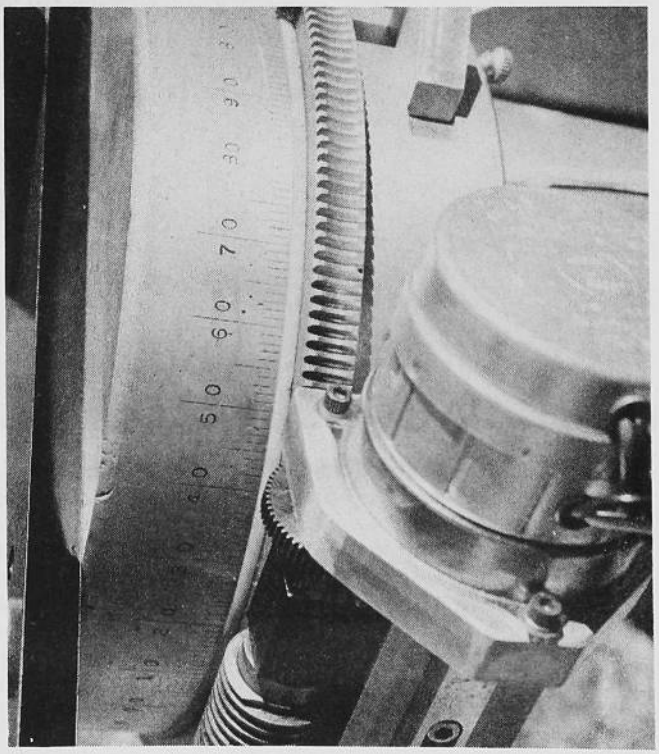
In the morning I drove into town,

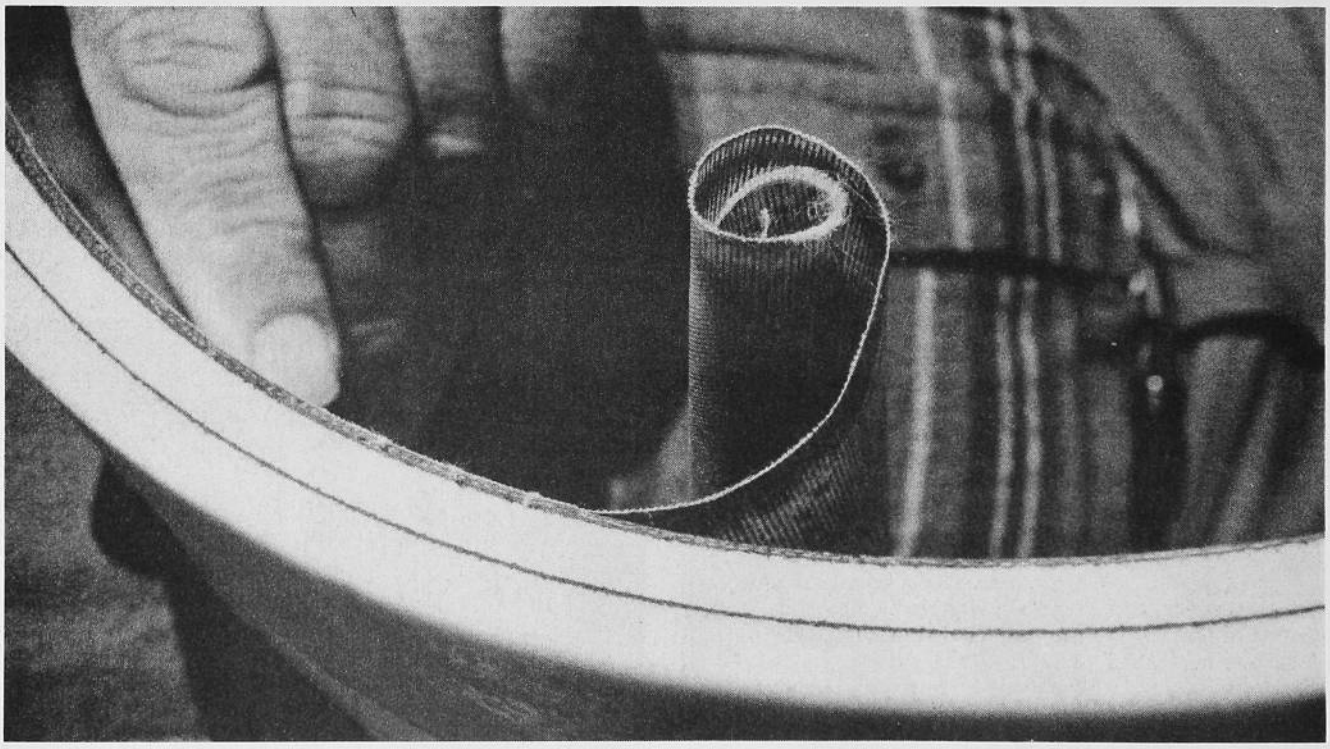


Coral rocks and shells surround the sign that welcomes visitors to Camp Wesumkee, where this year's Winter Star Party was held.



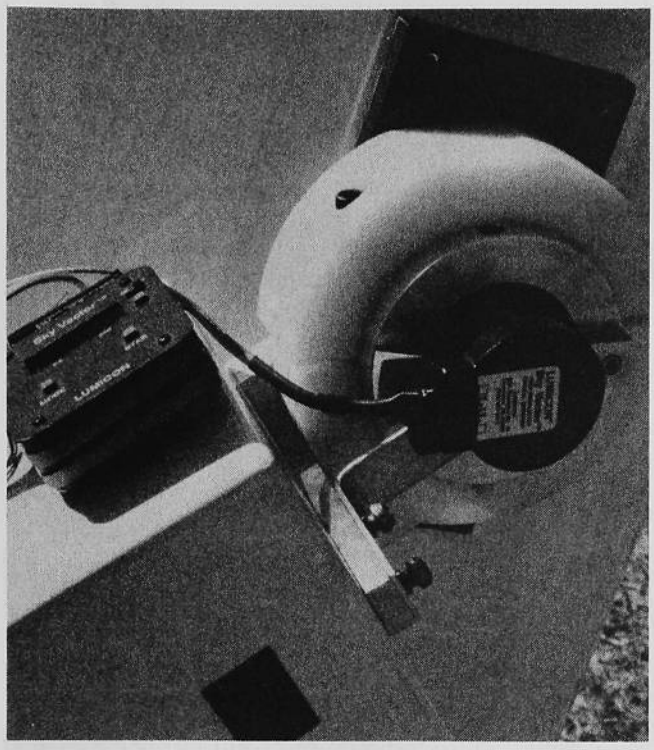
"Observing by the sea" could be the motto of the Winter Star Party. Telescope maker Tom Peters cast the aluminum parts for the mounting of his 10-inch f/5.6 Ritchey twenty years ago; he is still using the mounting.

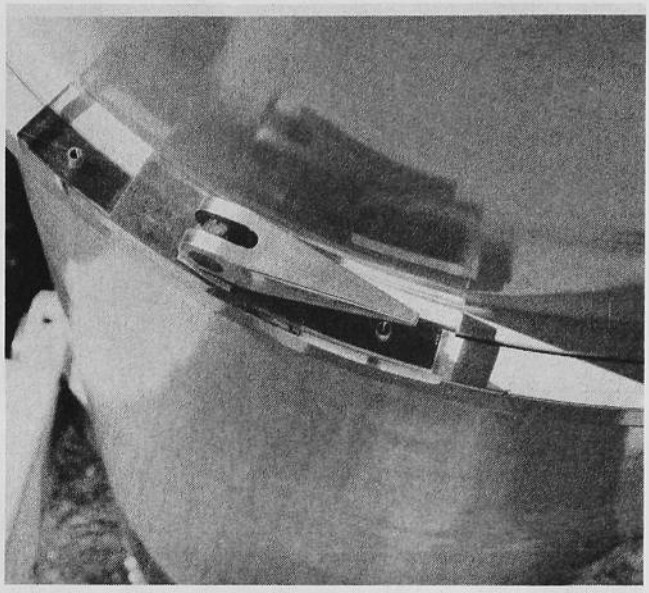


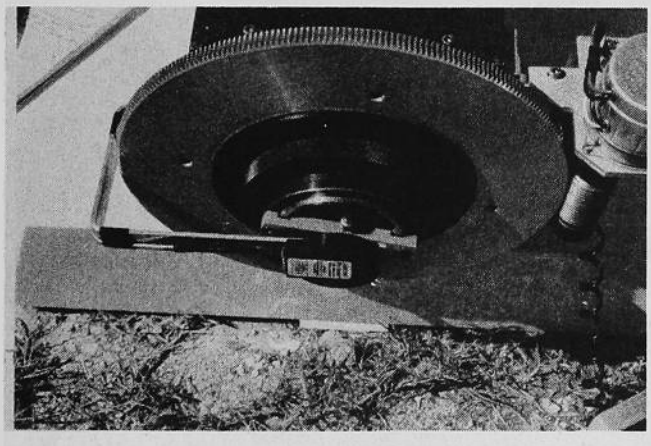


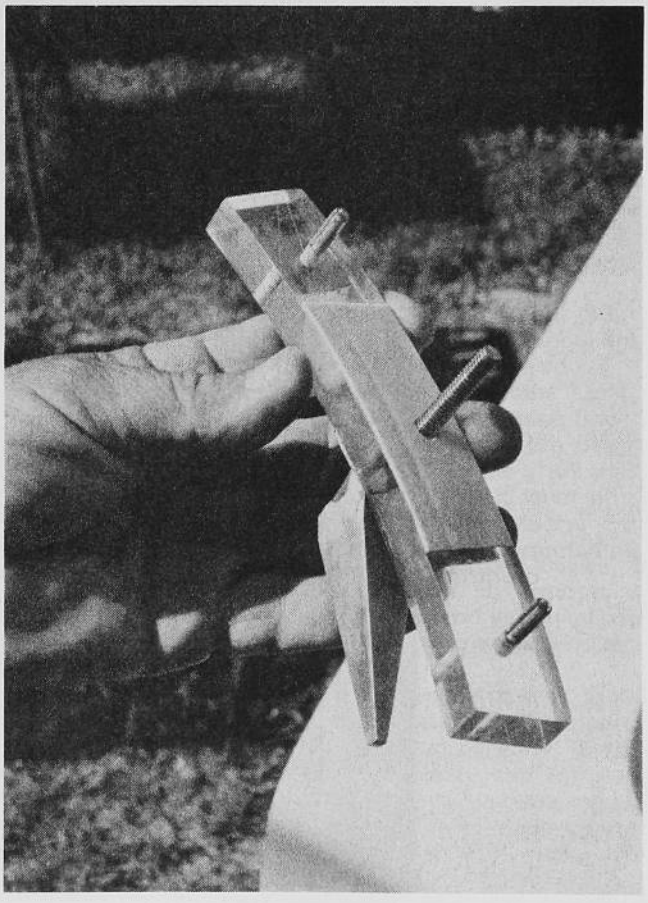
had breakfast, and went for a walk by the beach. I wandered along the shore looking for bits of sponge and coral in the heaps of seaweed. The day was warm and the Florida sunshine felt good after months of northern winter.

Talks began at noon. Tippy's presentation, on the distance scale of the solar system, was back by popular demand. Using rolls of toilet paper (Solar Heliocentric Illustration Tissue) to illustrate distance (at a scale of one square of paper to one million miles), Mercury was 39 sheets from the Sun. David "Eleven Comets" Levy and Tim Hunter (from International Dark Sky Association), who were sitting in front row, pitched into the project with considerable zeal, and pretty soon we passed the Earth and headed for the outer solar system. Tippy spooled off nearly four rolls of Scott tissues (1000 sheets, or one billion miles to the roll) before reaching Pluto. The audience, wreathed in tissue as we passed Saturn, cheered and clapped for each new planet.





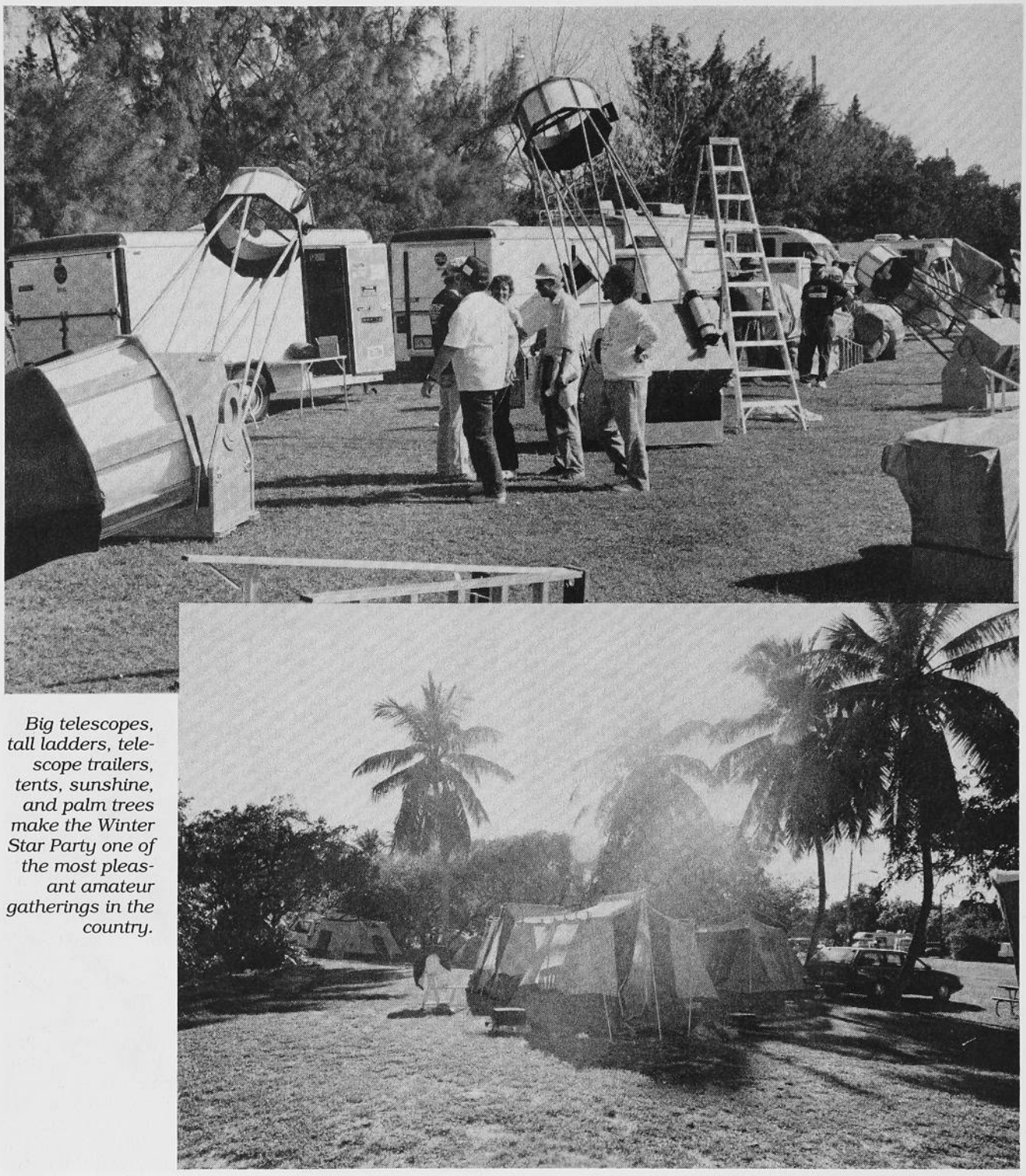




Queen Cassiopeia is the name of Walter Swentzel's 20-inch fork-mounted Newtonian. The tube is built up from foam and fiberglass layers, shown in cross-section (left). To attain a smooth , black matte finish, Walter used Dacron "peel-ply" on the interior walls. You can see the peelable layer partially removed in the picture left. Optical encoders for a Lumicon Sky Vector are mounted on the R.A. and dec axes, as seen above. Three plexiglas and aluminum clamps allow him to rotate the upper end of the tube into a comfortable viewing position.

After Tippy, observer and *S&T* editor Steve O'Meara described his discovery of a new feature on Mars. Describing Mars through the 60-inch reflector on Mount Wilson, Steve's voice took on an almost transcendental quality. He told of sitting on the telescope and seeing the equatorial volcanoes of Mars and the ghost craters in the polar regions along the rim of the polar cap. Steve and his wife Donna had stopped at Parker's the day before I had to research the new feature in Don's slide collection (Don is one of the ALPO Mars recorders). Steve showed a lot of Don's slides, and with a little squinting you could see the feature.

Along the road not far from the Camp Wesumkee sign was an interesting 20-inch f/5 foam-composite fork-mounted Newtonian built by Walter Swentzel. He calls the telescope "Queen Cassiopeia," a tribute to the area of Ft. Pierce that he lives in. Many of the street names are based on queen themes, like Queen's Cove or Queen Catharine. Walter picked the celestial queen of



Big telescopes, tall ladders, telescope trailers, tents, sunshine, and palm trees make the Winter Star Party one of the most pleasant amateur gatherings in the country.

Ethiopia for his telescope.

Walter is an enthusiastic proponent of foam, fiber, and resin technology. He constructed the mirror cell from $6 worth of fiberglass material, laying up hundreds of small pieces to form solid structural members. For the inside of his telescope's main tube, he used a special Dacron peel-up material that has a matte black finish. Declination bearings of Duralon plastic are compact and easy to make, and work smoothly.

Equally important for his telescope's performance are massive machined components such as the 3.5-inch stainless-steel polar-axis shaft with its large-diameter drive gear. Walter has also installed a Lumicon Sky Vector with 12-bit encoders so he can find objects quickly and painlessly.

Friday night was half clear and half cloudy — trouble was, the clouds always seemed to be where you'd point a telescope. But one thing I very much wanted to see was how well Tom Clark's 18-point flotation cell worked with his 2.13-

inch-thick 30-inch mirror. That's pushing the traditional limits! Although the seeing was nowhere near as good as it's been previous years, the fifth and sixth stars in the Trapezium were easy, and the bright stars showed clean, round images. Tom's going for an even bigger telescope — a 36-incher. Talk about aperture fever! When the sky finally socked in solid, I crawled into my sleeping bag and dropped off.

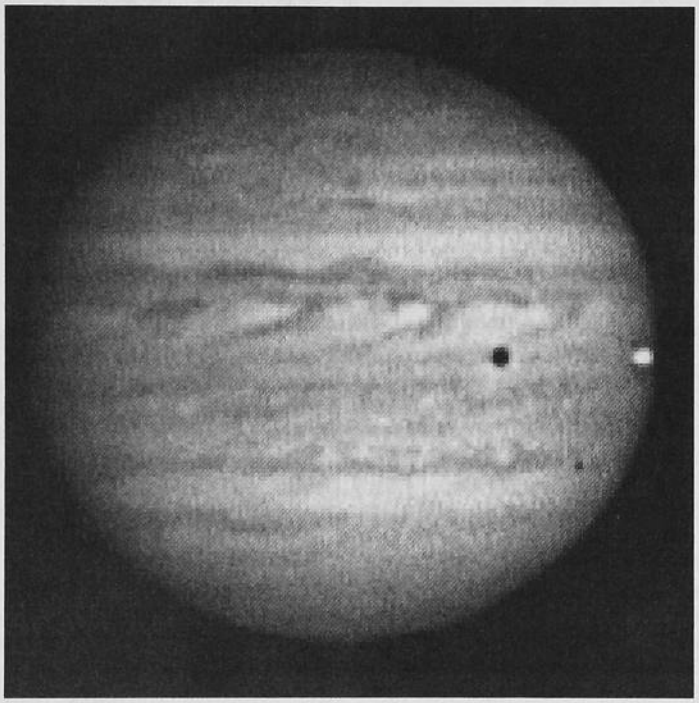
Officially, the Saturday program began at noon with my talk on digital image processing. If you read *TM* regularly, you know I've gotten into this stuff pretty heavily. What fascinates me is that today anyone with a PC can do the kind of image processing JPL was doing on mainframes fifteen years ago, and they can do it rapidly and interactively. Even more amazing is that a weekend programmer like myself can write software that's reasonably fast and considerably more innovative than the mainframe stuff.

Don's images are going to knock the planetary folks for a loop because astrophotography no longer competes on an even footing with digital imaging. A digital frame that's unprocessed looks as good as a high-quality photograph. Add processing and it's a whole new ball game.

Well, enough about my hobby horse. After my talk, Bob Victor spoke about the quest for young moons and planetary conjunctions, then Don told the audience why it's important (and fun) to observe the Red Planet, and comet-hunter David Levy (who had just discovered his eleventh comet) reviewed Comet Halley and the several comets named Comet Levy. I skipped out early to comb the field for new telescope ideas. What I found was old but solid.

Along the seashore near the mangroves and tide pools I spotted a short-tubed telescope on a real solid little mounting. Tom Peters, its owner, proudly pointed out how compact and solid the mount was. Twenty years ago, Tom said, he had cast the parts for the mounting using aluminum from discarded lawn-mower engines. I cast aluminum parts many years ago — those voids and bubbles are hard to avoid — so I appreciated the quality of his castings. The telescope turned out to be a 10-inch Ritchey-Chretien from Star Instruments; Peters is fond of the telescope but plans to replace it with a larger one.

The day was sunny and beautiful, so we wandered down to the coral beach and looked for life ocean in the tidal pools. Suddenly there was a scrabbling noise, and the plastic handhold for a kite skittered across the rocks, trailing 200 yards of string and a kite that was intent on heading out to sea! The owners of the kite watched as their the handle leapt into the water and was lost to them. The handle splashed across the tops of the waves.



A quarter-second exposure at f/25 captures almost all of the Jovian detail that Don Parker's 16-inch Newtonian can deliver.

Tom and I watched the kite as it sank toward the water — it looked a goner. But just as we thought all was lost, the kite pluckily gained altitude and flew higher again. A minute later it started to drop toward the water, but once again rose into the air.

That kite probably made it to Venezuela, caught in a rise-and-fall cycle. Each time the kite came down and slowed, the plastic handle dug into the water. The string then dragged on the kite so it would catch the wind and rise. But as the kite rose, the handle popped out of the water and skittered across the tops of the waves, decreasing the drag and dropping the kite again, and starting the cycle all over again.

Saturday evening was the night everyone had been waiting for; the forecast promised clear skies. Besides dozens of 6-inch refractors and 8, 10, 12.5, and 16-inch reflectors, half-a-dozen 20-inchers as well as a 25-inch and a 30-inch Dobsonian provided massive observing power. Because of the large number of telescopes, the viewing lines were only five or six people long, and waiting times were short. Jupiter, Comet Levy, the Horsehead Nebula, and Eta Carinae seemed to be the year's top observing attractions.

Around midnight, a barium cloud provided an unusual sight. The barium cloud released by a CRRES satellite shone as a 4-degree long by $^1/_4$-degree wide streak on the meridian around midnight. Over the course of an hour, it gradually faded away. I turned in around 2 a.m. and set my alarm for 4 a.m. to see the summer stars rising.

The hour before dawn was spectacular and beautiful. The palm fronds clacked and clattered in the breeze off the ocean; the highway was silent. The camp was quiet, most of the observers were snoozing, and only a few telescopes remained uncovered. Sated for the time with sunny days, green plants, and summer smells, I felt calm and peaceful. It was cold, true enough, but the glow of the zodiacal light seemed warm and I wanted to drink in all I could of Scorpius standing high on his tail. As dawn came and washed away the stars, I knew I'd be back for another year's Winter Star Party.

— Richard Berry

Low-Tech R&D and Off-the-Shelf Parts for Super-Big Telescopes

I guess I'm an odd duck. As an amateur telescope maker halfway gone professional, I'm neither fish nor fowl. On the one hand I sell telescopes, and on the other hand I love to show amateur telescope makers what I've learned about building telescopes. This story is from the amateur side of me; it gives nuts and bolts answers to hundreds of questions I've received.

Ever since "The Making of Obsession 1" was published in *TM#35*, amateur TMs (and some professional TMs too) have asked me for blueprints. In fact, when my little Obsession Telescopes company began commercially producing 20- and 25-inch telescopes in March 1990, I got so many calls I had to buy an answering machine. But the calls weren't for orders for telescopes. Rather, they were calls from all TMs who wanted construction tips!

Well, here it is. The "secrets" of the Obsession are really all low-tech stuff, and they work. They're low-tech because going commercial demands simple solutions to construction problems. If the solutions are not simple, the product becomes too expensive to sell. (The fact is, I just can't custom-design every doggone fastener.) For the Obsession, my design philosophy is this: If I can't get it off the shelf, I re-design around whatever I can get off the shelf.

Threaded Inserts

The best example of a low-tech solution and an off-the-shelf part is the threaded insert. These have a threaded center surrounded by metal "petals." I use them to attach the aluminum tubing to the wood rings on the upper tube assembly.

With threaded inserts there's no need to epoxy the tubing to the wood anymore, and no need to use a heavy threaded rod which prevents you from using a Novak type of spider (the rod gets in the way of the spider mounting screws). There's no need to custom machine-threaded plugs and press-fit them into the tubes. These lightweight off-the-shelf metal inserts eliminate all that.

Simply press the threaded insert into both ends of the tubing. I put a machine screw with the same thread as the insert into my drill press and spin the insert up to the chuck. Next I stand the tube on the table and push the insert into it by bringing the chuck down with the drill-press handle (with the drill press not running).

You can also tap them into place with a short bolt and a hammer. Once these babies are inserted they never come out. Now you can attach the wood rings or anything else to the ends of the cage struts with ordinary $^1/_4$-20 x 1.25" machine screws. Best of all, the inserts allow for future disassembly if you want to rebuild that part of your scope.

They are cheap, only 55 cents apiece. They weigh next to nothing and come in assorted sizes and threads. I use part #3046-4 for 1.25" tubing and part #3047-4 for 1.5" tubing. It wasn't easy to find these. I ordered a catalog from every fastener company listed in the Chicago Business-to-Business Yellow Pages. After reviewing a two-foot stack of this industrial literature, I finally found them at PMC, Plastiglide Manufacturing Corporation.

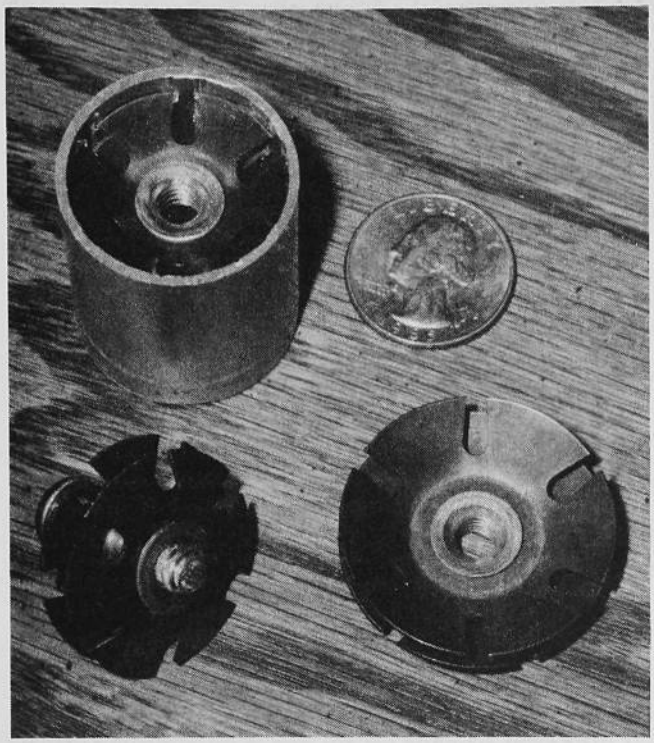
Kydex

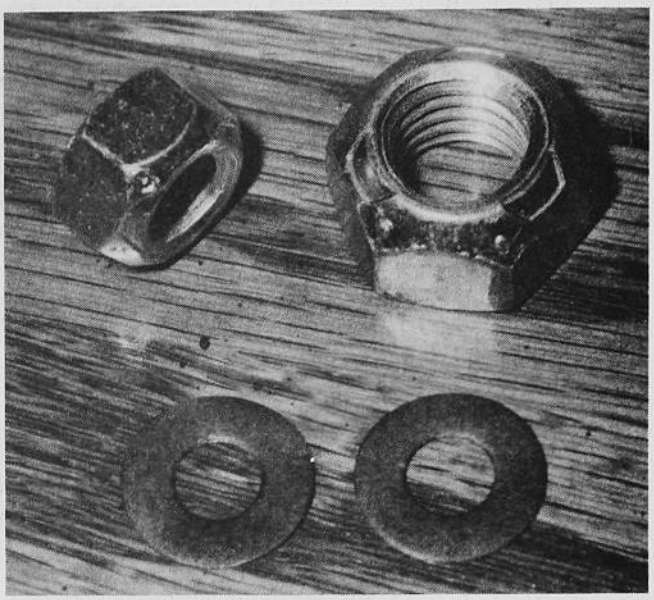
The light baffle in the upper tube assemblies described in *TM#35* and *TM#37* was made of DuPont Mylar. It's typically offered in a 20" x 50" size for use in the graphics industry. Although it works well, two pieces are necessary to get all the way around on a big scope. Furthermore, because it is transparent, it has to be painted black.

I wanted something that was long enough so that there would be only one seam that could be hidden under the focus board. I wanted it to be black through and through so that when it got scratched, it would still be black. It had to be cheap, easy to cut and drill, and waterproof. It had to be dull on one side to absorb light and shiny on the outside for the sake of appearance. It had to accept double-sided tape. It had to be rigid enough to maintain its shape. And of course, it had to be available off-the-shelf.

While waiting for the clerk at a plastics warehouse, I picked up a batch of sample chips and stumbled upon Kydex. After testing it against many other sheet plastics, Kydex came out on top. Kydex, an acrylic-PVC, is quite scratch resistant. It is the same stuff Orion, the telescope catalog retailer, sells for their Dew Cap/Lens Shades. I've been using it as a light baffle for almost two years and it works extremely well.

Kydex is sold in 4x8-foot sheets in nine thicknesses, from 0.028" on up. I use the black 0.028" for





Threaded inserts (left) and all-metal lock nuts (above) make standard hardware tubing and threaded rod function like machined parts. The inserts put threads in the end of tubing; the lock nuts put shoulders on bolts.

my light baffles. The dull side has a "hair cell" pattern. Its rigidity is excellent, and when it's installed with the shiny side out, it looks great. I pay $35 per sheet.

Kydex is primarily sold as a commercial wall covering. It's durable and impact resilient, so it won't dent like aluminum and it's nearly as lightweight. In addition, it can be trimmed with a sharp knife and drilled for the spider screws. If you feel creative, Kydex is available in a rainbow of "33 attractive colors and 5 surface patterns."

Beware, however, because Kydex deforms at 180 degrees Fahrenheit. Don't wrap your scope in clear plastic during the day at a star party. The greenhouse effect under those conditions is severe enough that the Kydex can overheat and warp. Cover your scope with one of those ubiquitous blue plastic tarps.

Kydex also works well to retain the six floatation-cell triangles. Cut out a 2-inch-wide ring to cover the apices (plural of "apex") of the triangles. Attach them with double-sided tape. Kydex is rigid enough to prevent the triangles from rotating, yet it's flexible enough to allow them to pivot slightly.

Speaking of double-sided tape: I use it to attach the Kydex to the upper tube assembly. Double-sided tapes are versatile. Cloth carpet tape, 3M's weather-stripping tape, and automotive trim-mounting tape are just a few examples. I buy it in $1/2$"-wide rolls. Put a thin coating of contact cement on the inside edge of the cage rings and let it dry completely; the tape sticks better to this treated wood.

Felt Tabs and Floor-protector Pads

You can make fantastic mirror cell "points" with felt tabs. They are self-adhesive, soft, and bump-absorbing, and come in a variety of thicknesses and diameters. They're very cheap and you can't beat the ease of installation. Just peel off the paper backing and stick 'em on the floatation triangles. They're used under furniture items and glass desktops, and they're available in most hardware stores.

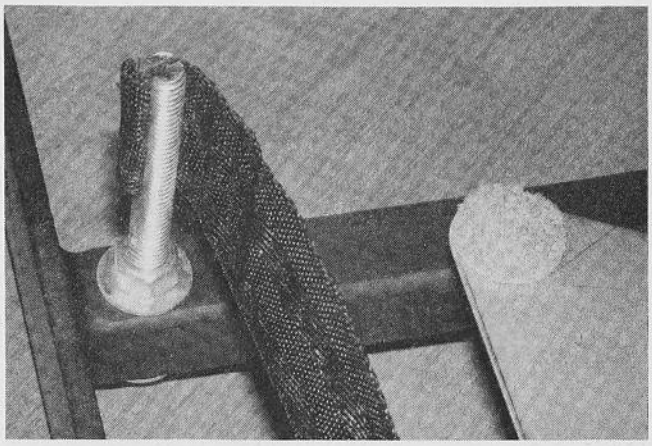
For those of you with a bad case of aperture fever get "floor-protector pads." Used under chair and table legs, they're also self-adhesive. They have what looks like a pad of soft carpet on them. These are squish-resistant under the big heavy mirrors so popular today. I'm using 1"-diameter by $1/4$"-thick extra-dense felt tabs on my scopes. Just knowing my 25-inch mirror is sitting on them makes the bumps in the road seem softer.

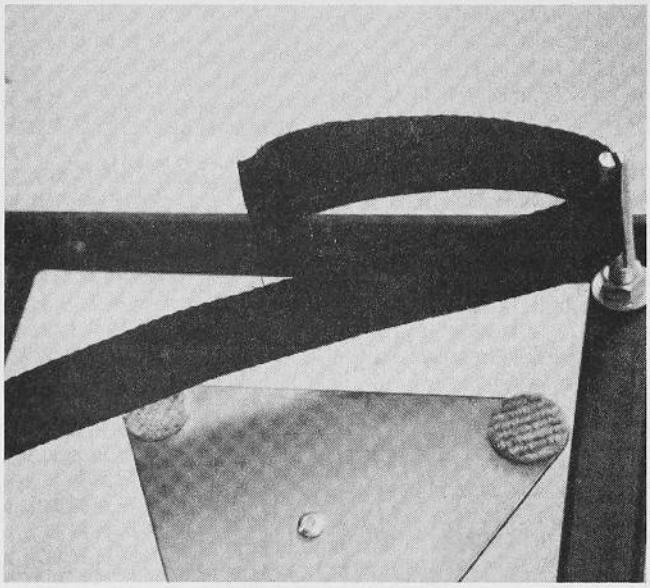
All-Metal Lock Nuts

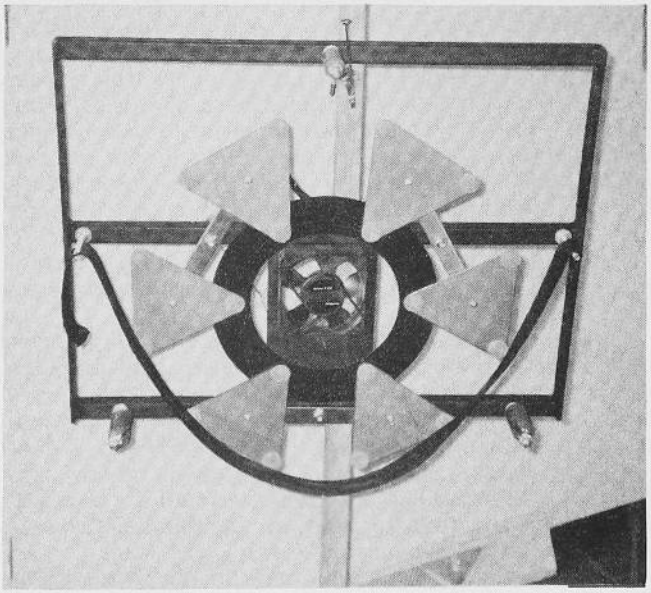
Lock nuts are quite versatile. I use them under the three balance-bars in the mirror cell. Instead of epoxying a nut to the collimation bolts (as I described doing in *TM#35*), I now place a $3/8$"-16 all-metal lock nut on each collimation bolt. The three bars of the 18-point floatation cell simply pivot on the beveled top surface of the lock nut. The lock nuts are tough to spin on, but once they're in place they won't turn loose. That's important when you collimate the primary: the bolt and nut must turn together driving the bar up or down. To aid placement, put a little Vaseline on the bolt before installing the nut. Don't try nylon insert lock nuts for this, they slip.

I also use these lock nuts as stops on $3/8$" diameter by 5-inch-long eyebolts on the wheelbarrow handles (thank you, Ron Ravneburg, for the tip in *TM#35*). Eyebolts are cheap and durable, and won't break off when you smash them into the sides of your vehicle or a door jam when loading your scope. The eyebolts remain captive using all-metal lock nuts recessed into the handles. Don't drive the nut up tight to the handle. Leave it sloppy so the eyebolt is easy to turn.

My wheelbarrow handles mate to the rocker sides via solid brass inserts. These 1"-diameter by 1.25"-long brass "plugs" are threaded internally to accept the eyebolt on the wheelbarrow handle. The outsides are knurled and they are permanently glued into the rocker sides. Unfortunately, I have to custom machine these brass inserts. If someone knows of an off-the-shelf







Who says a mirror cell has to be complicated? Two split bolts and a sling made of webbing are radial supports. Behind the mirror (bottom photo) an 18-point flotation system gives longitudinal support.

solution to replace them, please let me know. You won't get a free telescope, but I'll spring for one of our company T-shirts.

Split Bolts

I hatched this idea because I was sick of sweat literally dripping off my face onto the optical surface of my 25-inch mirror. Trying to tighten the sling from the top end of the mirror box is very difficult and frightening. I couldn't bend over and reach into the box properly to tighten the buckle on the sling. As a result, when the scope was assembled, the mirror wouldn't be sling-supported when the scope was pointed towards the horizon. There had to be a better way to draw up the tension on the sling more and to do it easily. Enter split bolts.

I use two $^3/_8$"-16 by 4"-long fully threaded hex head machine bolts to retain the sling. Both bolts are "split" two inches in from the end with a band-saw cut down their length. The bolts are installed into the middle "rung" of the tailgate (see *TM#37*) on opposite sides of the primary. Ordinary $^3/_8$" nuts are spun down over the splits and tightened up against the tailgate rung.

Next, I place the ends of the sling webbing into the "splits." Now when I install the mirror, I loosely lay the sling around the side of the glass and attach the very bottom of the sling to it with a small piece of double-sided tape. The tape only helps to keep the sling from slipping off the side of the mirror when the mirror box is in the vertical position.

After the scope is set up and rotated down towards the horizon, I loosen one of the split bolts with a wrench from the back side of the tailgate and rotate it until all the slack in the sling is drawn up. As I turn the bolt, the mirror rises effortlessly until it almost touches the upper off-center pin. With another wrench I reach through the tailgate and tighten the nut to lock it in place. The whole process takes about 20 seconds, and it's all done from the back side of the mirror cell with the telescope fully assembled.

"Levelers" as Collimation Knobs

To avoid machining special bolts and knobs for collimation, I experimented with ordinary "levelers." You've seen these, I'm sure, the adjustable things you find under file cabinets, refrigerators, washing machines, etc. They are a good example of how a relatively simple item can solve many requirements. I could have used ordinary machine bolts, but then a wrench would be required to collimate the primary. The levelers have a plastic knob built in to eliminate altogether the need for a wrench. You can even turn them with a mitten on.

The following is a description of the leveler I use. The $^3/_8$" threaded portion is 2.5" long and is factory-welded to a 1.125"-diameter metal disc. Over the disc, the manufacturer fits a gray plastic cap to prevent the metal from scratching the floor. This round metal disc and cap make a solid and gripable collimation knob. What's more, because levelers are designed to support heavy loads, you can lift the mirror box with its primary out of the rocker and set it right on the ground. Even the biggest Dob in the world won't squash these "collimation knobs." For a buck apiece they can't be beat.

Black Stain

Everyone knows the inside of a telescope has to be painted black. Ebony-colored Olympic Stain was my answer here. It is available in an oil or latex base. It covers in one coat, it's very black, and no primer is necessary. It's cheap, waterproof, and extremely long lasting. A gallon will cover a dozen Dobs.

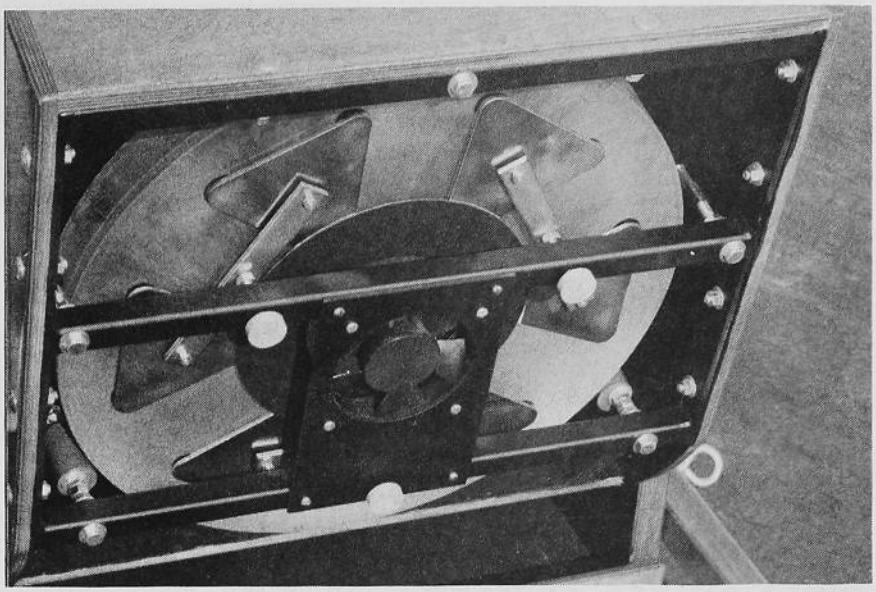
Plastic Knobs

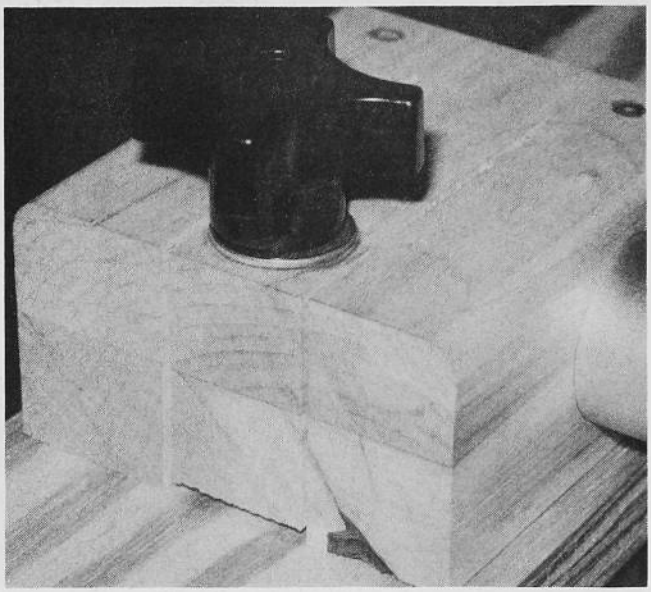
A great source for plastic knobs at reasonable prices is Reid Tool Supply. Get their catalog. I like Reid's 4-prong plastic knobs because you can turn them with a mitten on. They are made from black phenolic with threaded brass inserts. If you can't find the knob you need in Reid's, forget it.

Second-generation Split Blocks

The split blocks described in *TM#35* work okay, but they have a couple of problems. First, it's difficult to bore a hole that is big enough to insert the poles easily, yet small enough to grip them firmly. Second, split blocks are prone to fracture at the end opposite the split. This is not good when it happens while you're observing at a dark site.

My cabinet maker, Pete Welbourne, deserves credit for developing a better split block. He sections the middle third of the block perpendicular to the pole the block holds. His two cuts don't extend all the way through the block, and he dadoes the back of the middle third out slightly. When you tighten the knob, the middle third of the hole moves inward. This means that you can bore the block to a slightly larger diameter so that it will accept the poles, but the block will still grab the poles very tightly. Best of all, the blocks won't break.





Nice-looking collimation knobs! The secret is that they're ordinary furniture levelers and cost only a dollar apiece. Below: Splitting the split block makes for easier insertions and a firm clamping action.

Bondhus Balldrive

Everyone who owns a Novak secondary holder will want to try this. Ordinary screwdrivers are difficult to insert into the three slotted-head collimation screws on the back of Novak secondary holders. The screwdriver often slips out of the slot and it's a pain to reinsert it while you are looking through the focuser and not at the screw head. Furthermore, getting to that third collimation screw under the spider vane is a real trick because the vane gets in the way of the screwdriver shaft.

Pete Smitka (*TM#35*) found a neat solution to this problem by using a "Bondhus Balldriver" instead of a flat-bladed screwdriver. Remove the three slot-head screws from any Novak secondary holder and replace them with the button-head or socket-head screws. Purchase a matching Bondhus balldriver from Reid Tool Supply.

The end of the balldriver shaft has a ball with a hexagonal cross-section. This tool allows for a fast and easy entry at a considerable angle. It seats itself in the screw head making blind insertion much easier. You can concentrate on the collimation images in the focuser and tweak the ball driver with greater control.

Ebony Star

Wilsonart manufacturers a counter top laminate called "Ebony Star," #4552-50, that is slicker than #7181 Tweed Formica (see *TM#35*). It has a hard, stippled surface and is speckled black in color. This material works very well on large Dobs, because it noticeably reduces friction. Besides, any product with a name like Ebony "Star" has to work great. This stuff is expensive at $70 for a 4x8-foot sheet.

Glass Board

Another laminate I use is "FRP," more commonly called glassboard or fiberglass board. It is sold as a wall covering for the food-processing industry. The hard nonporous surface is impervious to most solvents so it can be cleaned efficiently.

FRP is a fiberglass product with a smooth mounting surface that takes contact cement well. The business side has an extremely hard pebbled surface. The bumps are so large that they may be felt while guiding the scope at high power unless the Teflon pads are quite large. On the bigger Dobs this is no problem because the pads are large enough. I am currently using a glassboard that is 0.090" thick. It's sold in 4x8-foot sheets in white, gray, almond, or beige for around $28 at lumber yards.

Dress up your telescope with an opaque light shroud. Riptide fabric looks good and works wonderfully to keep out dirt, stray light, and air currents.

FRP works best on scopes in the 20-inch to 40-inch(!) range. The first time I tried FRP on my 25-inch scope, I was thrilled. The telescope is truly effortless to move, and considering that it weighs 265 pounds, that's remarkable. It feels like the scope is sliding on glass.

This bearing material may be too easy for some folks. Anything over a 5 mph breeze turns the scope like a giant weathervane (this scope has an eight-foot lever arm), but that's the way I like it. Besides, you can't observe here when there is a breeze anyway because the wind chill will kill. "Dobson's hole" at the zenith doesn't exist for scopes mounted on FRP, and hand-tracking at 900 power is not an idle boast. Too bad the seeing in Wisconsin seldom allows more than 400 power.

Silicone Car Wax

Sometimes at star parties, I tell people that the great buttery feel of my scopes is butter, but it's really silicone. I tried silicone grease on Obsession 1 (*TM#35*) to eliminate the difference between static and dynamic friction. It made the motions smoother, but I found that it had two disadvantages. First, it became stiff in Wisconsin winter temperatures. Second, it attracted dirt faster than a new primary. I learned this with the dust at Texas Star Party. After only a day, the bearing surfaces were so contaminated they were the color of the desert. Next I tried silicone spray. Intended for use as a dry lubricant, it didn't work either. Something in it gums up after a couple of days, making the scope stiff again.

What I needed was the silicone, not the carrier, so I tried ordinary Turtle Wax. It worked better than I expected. Almost any commercial brand of car wax will work as long as the main ingredient is silicone. Just spread it on with a rag, let dry to a haze, and then buff. Silicone car wax will noticeably decrease the friction on any Dobsonian, large or small. When I wax my car in the spring and fall, I will do my scope bearings, too.

Virgin Teflon

As indicated in "The Making of Obsession 2" (*TM#37*) I use etched virgin Teflon. The etched surface accepts contact cement so there are no nail heads to scratch the laminates. For the past year, I have been using Teflon that is a mere $^3/_{32}$" thick. Teflon is expensive. Why pay for thick Teflon when only the top few layer of molecules do all the work anyway?

In his article, "How to Control Friction in a Dobsonian" (see *TM#8*), Richard Berry, recommends 13 to 15 psi loading on each pad. After making over 30 large-aperture Dobsonians, I gotta tell you he did his homework. Deviating from 15 psi in either direction increases the friction and makes the scope lethargic.

Riptide

A covering for an open-truss design like my Obsession is a must. It is an essential element in preventing image fogging and loss of contrast from stray light entering the optical path. It also keeps dirt off the primary when you climb up and down your ladder, and even more important, it deflects falling objects from crashing onto your expensive primary. Eyepieces, eyeglasses, filters, books, cigarette ashes, and curious children all have a great affinity for high-quality paraboloidal optics.

The fabric that I use is called Riptide. Available from JoAnn Fabrics, a national chain, Riptide is a light-

weight, black, ripstop nylon that is dull on one side and semi-glossy on the other. The dull side is sewn to face the inside of the scope and the glossy outside looks attractive. It breathes quite well so, there are no tube currents yet it deflects the observers body heat away from the optical path.

Riptide is nearly impossible to tear. Although Riptide is not waterproof, it handles heavy dew well. To clean it, just toss it in the clothes dryer on low heat.

At $6 a yard (60 inches wide) it's affordable. Be sure to ask for it by name. One unfortunate soul bought a generic ripstop nylon to make his own shroud only to discover it was not color fast in heavy dew. The dye ran out and dripped all over his scope, including his new 20-inch mirror!

The upper end of the shroud should be hemmed and fitted with a draw string and slider. Nifty little sliders can be purchased from Campmor, a camping catalog outfit. They are actually called Fastex Lock with Wheel and sell for 25 cents each. The end down at the mirror box uses plastic grommets and four bungee cords that wrap around the split blocks. The bungee cords keep just the right amount of tension on the shroud so it stays taut. Strangely enough, ripstop nylon expands when it gets cool or wet and contracts when it gets warm. I have seen many black nylon light shrouds at summertime star parties that pulled off of their Velcro fasteners or, worse, actually ripped out the seams in the hot sun. Bungee cord attachments prevent this.

The draw string around the upper tube assembly can be adjusted to pull up the shroud snugly, especially when it expands in the cool damp of the night. It counteracts the force of the bungee cords yet allows for easy placement and removal. Speaking of placement, it only takes a minute to install the shroud at night. After the scope is fully assembled, point it down to a comfortable height and pull the shroud over the whole telescope like a big sock. Attach the bungee cords, pull up on the draw string, and observe.

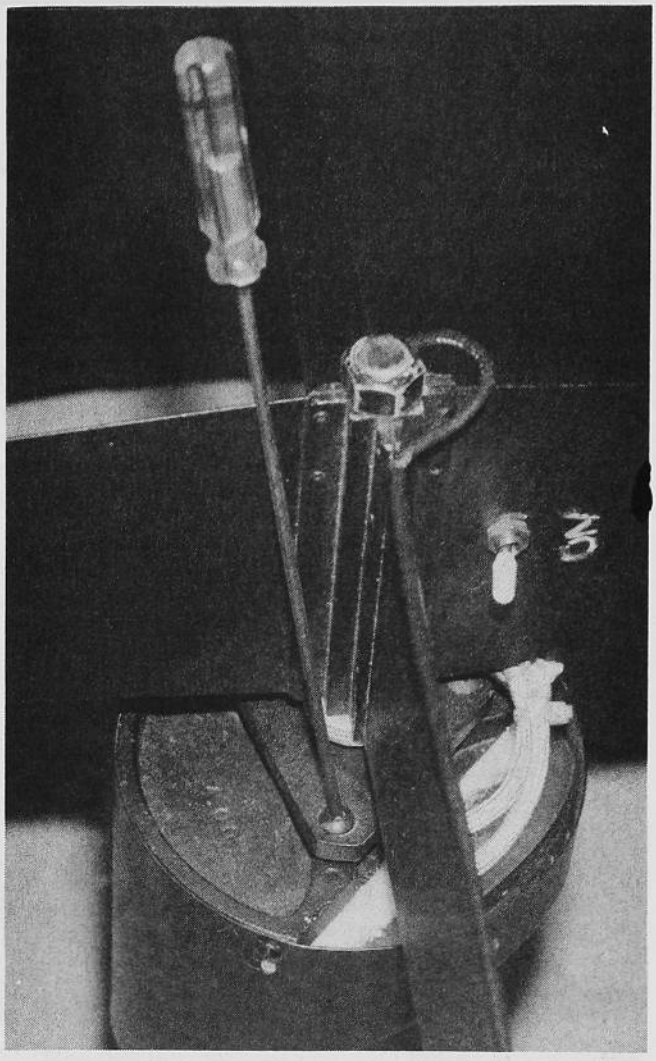
15-Watt Light Bulbs and Dew

Large-aperture primary mirrors rarely dew up in use. They dew up in storage. Dew is a chronic problem in the more humid areas of the country. Generally, dewing occurs when moist air condenses onto the surface of the mirror.

This usually happens when the telescope is stored in a garage or shed. The mirror cools during the night. When the sun rises in the morning, it warms the building and the air inside. Large mirrors have considerable thermal inertia; that is, they lag behind the rise in air temperature. The warm, moist air in the storage area condenses on the still-cool mirror. This cycle can expose the coating of the primary to repeated, daily dewing. Air pollution in the dew (it's actually acid dew) will rapidly deteriorate the coating.

Dewing can also occur in a trailer or enclosed vehicle like a van. Leave the doors or windows open so the sun can't warm up the air as much and park in the shade. If a garage or shed has electricity, a simple 15-watt appliance bulb will very effectively prevent dewing. Place the bulb under the mirror in the rocker unit. Be sure to support it properly in a small fixture so it doesn't contact the wood or mirror cell.

Don't use more than 15 watts. Higher wattage bulbs are overkill and can cause a fire. Leave the bulb on permanently in storage. The slight warming of the primary that it provides will prevent dewing.



A balldriver eliminates the need to be perfectly squared on when you adjust a secondary mirror. The "ball" is a ball-shaped section of hexagonal rod that acts like a combination universal joint and Allen wrench.

Heat Ropes

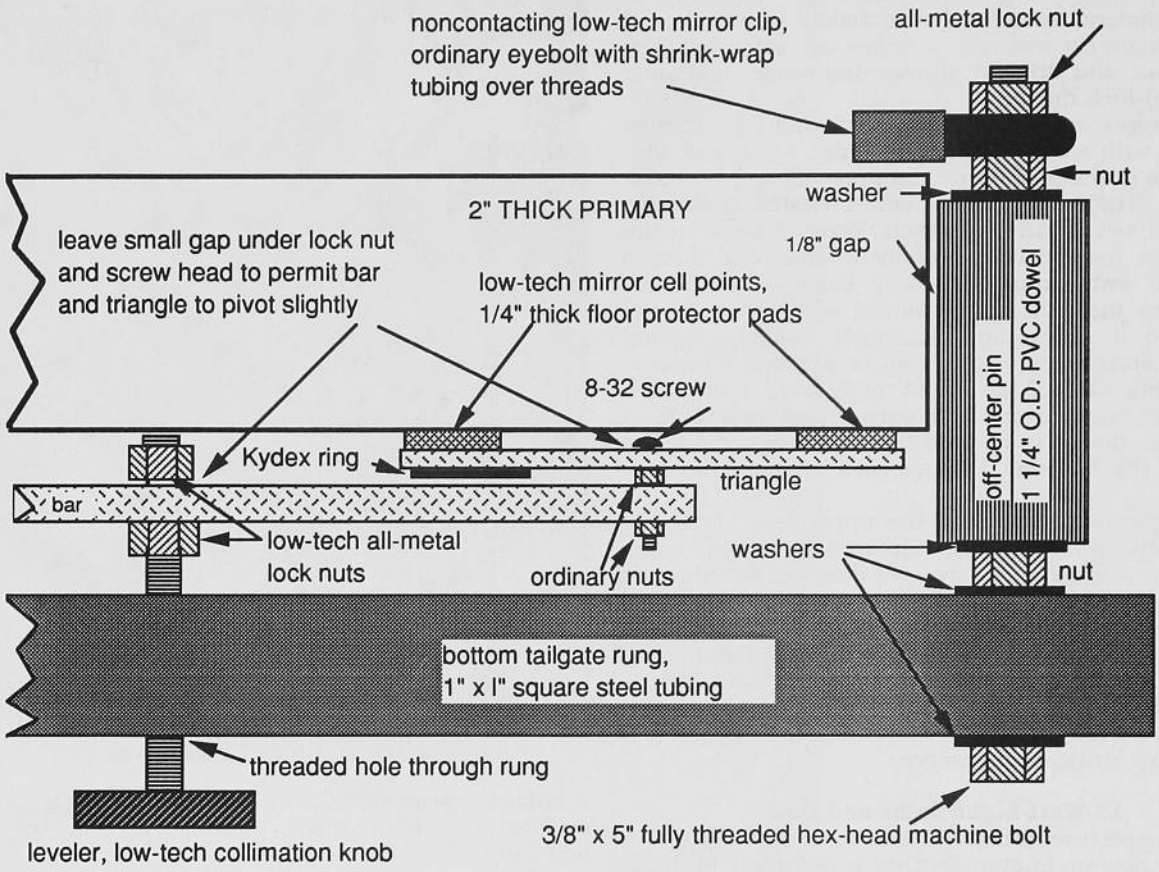
The secondary mirror often dews up in use. It can be dried by blowing warm air on it with an electric hair dryer or 12-volt heat gun available from various suppliers. But a slick way to prevent dew from forming is to use a heat rope. Heat ropes about 24 inches long are available from Jerryco, a surplus catalog outfit. Someone told me heat ropes are actually the heating element from automatic coffee makers.

Lay one out on the back of the secondary between the glass and the polyester batting, or glue it on with silicone caulk. Connect it to a 12-volt power source like a Porta-pak. A heat-rope will generally prevent dewing, but can't remove dew. These inexpensive heat ropes (about a buck apiece) also work great around the window and lens of the Telrad. Attach with a few dabs of silicone caulk.

Hole Reinforcements

Fast Newtonians require accurate collimation. Standard procedure for most observers is to use a Cheshire eyepiece with a centering dot on the primary. You

LOW-TECH 18-POINT MIRROR CELL



Note: 1/8" gap between side of mirror and off-center pin for sling. Nothing contacts the side of the mirror side except the sling. The off-center pins serve only to keep the mirror captive during transport.

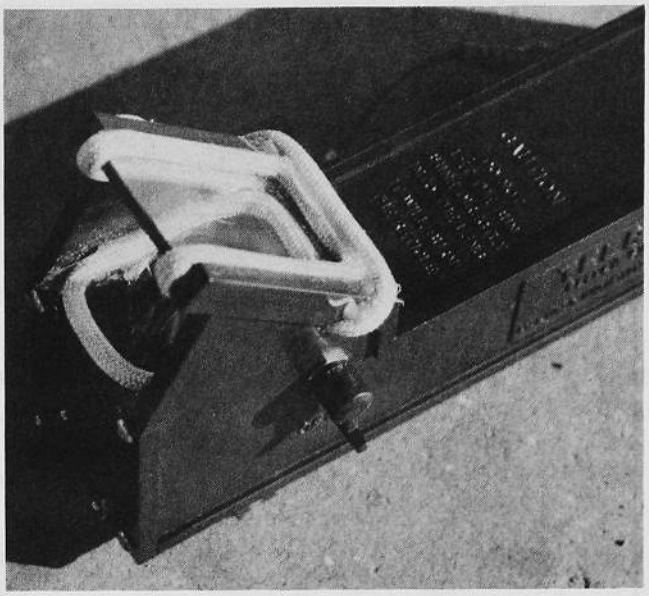
Note: The bars and triangle simply pivot on top of the nuts slightly to provide equal support at every point.

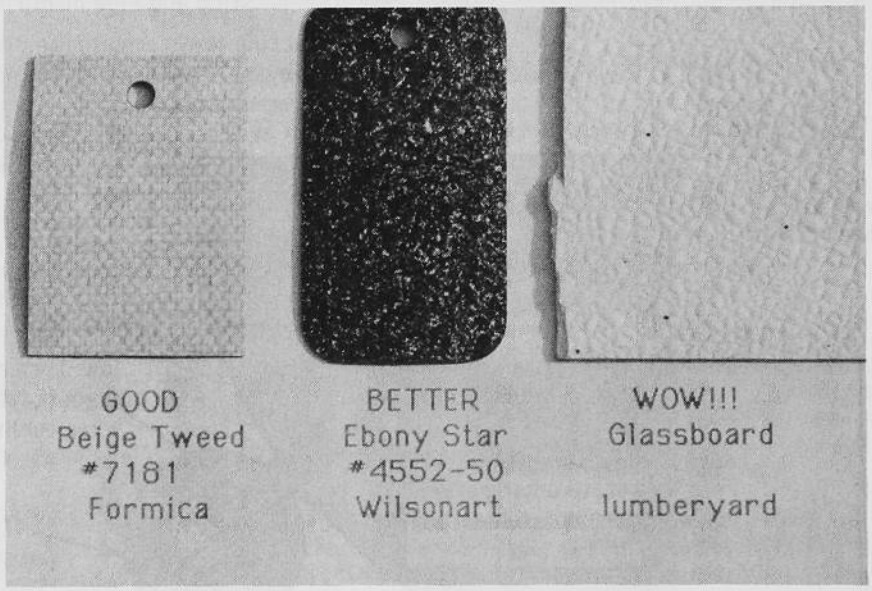
Not drawn to scale

align the dark spot of the Cheshire with the center dot on the primary. But this can be difficult on the big scopes in use today. Eight and ten foot focal length reflectors are becoming commonplace and it's tricky to eyeball that little dot so far way.

Pete Smitka thought up a clever visual aid to overcome this problem: hole reinforcements. They make great center dots. (You know what they are — they're those little paper circles you lick with your tongue and put over the hole in the page in a loose leaf folder to prevent the paper from tearing.) Color one with a black marking pen, lick it and place it in the exact center of the primary.

When you collimate, you'll see the dark spot from the Cheshire and a dark ring on the primary. It's quite easy to see the ring as it moves towards the spot because the ring is larger. When the ring completely surrounds the spot of the Cheshire, you know that you're right on. The spot just fits into the ring so that if you're off a tiny bit, it is readily apparent. Collimating the primary this way is fast and accurate. The little reinforcement sticks to the mirror tenaciously. My 25-inch mirror has been washed four times and it's still on.





Heat ropes (above) let you put a little warmth where it's needed. They're great for killing dew. Below: Glassboard is slicker than Wilsonart and makes super bearings.

Why?

My low-tech R&D with off-the-shelf materials has helped me considerably. Without these materials, building a couple dozen Obsessions a year would be neither feasible nor cost effective. By now some of you may be thinking I'm foolish to give away my "secrets." Indeed, a couple of competitors have incorporated some of these ideas in their scopes. Here are two reasons why I'm telling you what I've learned.

First, if it wasn't for *Telescope Making* and amateur telescope makers, I would never have gotten back into astronomy. That's a debt I'd like to repay, so my articles are one way of saying thanks. Second, I don't care if "the other guys" copy me. I'm definitely not out to corner the large-aperture telescope market.

Besides, with scopes that can cost as much as a small car and require spousal consent, it's not much of a market anyway. I already have a career that pays me well. If I want to make money I go to my dental office to drill, fill, and bill. When I want to have fun, I build big telescopes and haul them to dark skies.

Suppliers

The following is a list of suppliers. For the sake of completeness, I've included items discussed in my articles in *TM#35*, *#37*, and *#41*. Please remember that you are at a considerable disadvantage when you order some of these things. Distributors and wholesalers are used to taking orders for thousands of widgets at a time. You can almost hear them laughing over the phone when they answer, "You only want three?!"

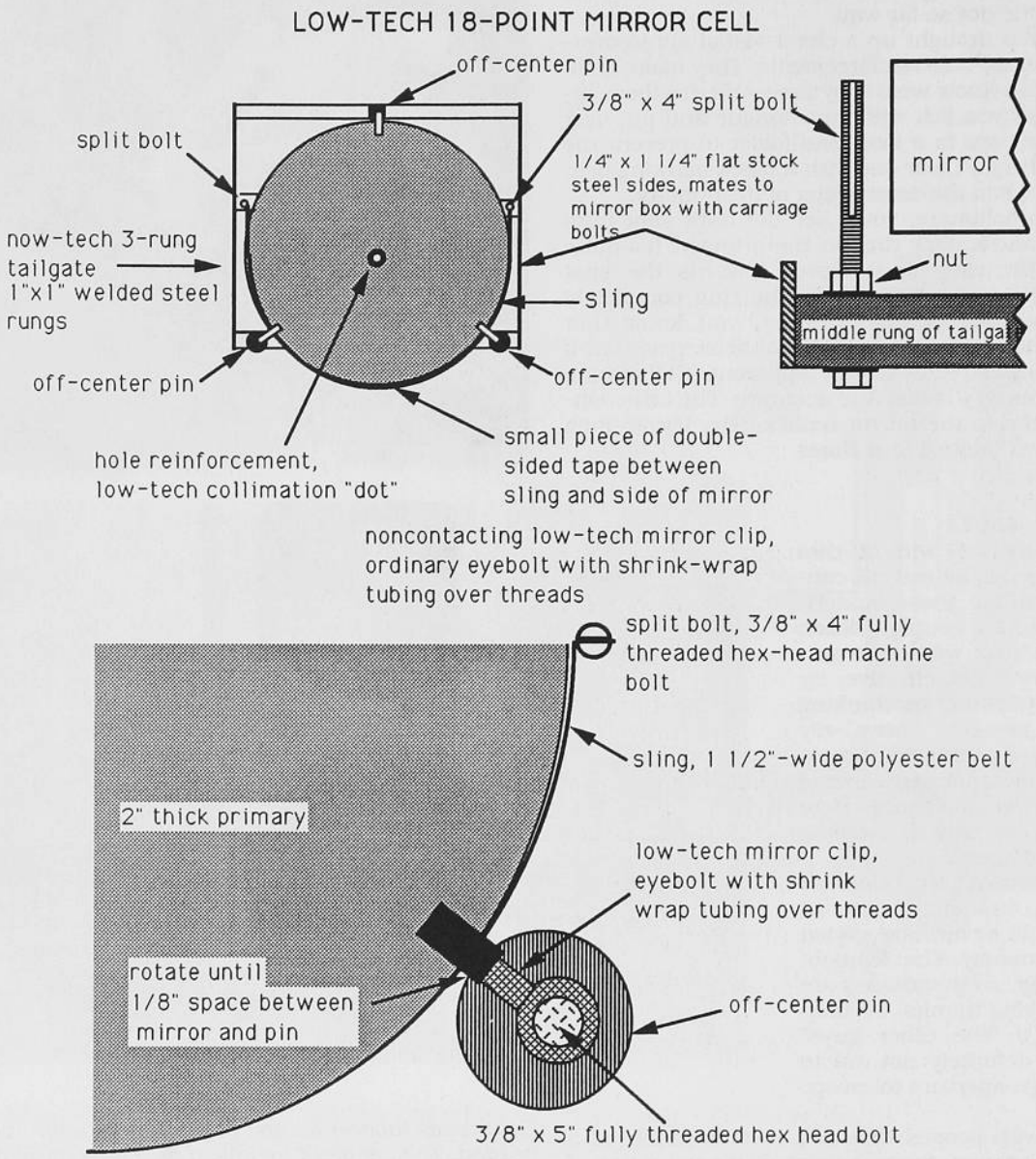
If at all possible, obtain a catalogue ahead of time so you can decide exactly what you want and sound reasonably intelligent when you order. Some companies have minimum orders, don't sell retail at all, won't sell to anyone that hasn't passed their credit department, or simply don't want to bother with your tiny order. Be prepared for this. Identify yourself and explain your project. Beg them. Offer to pay for it in advance or have them send it COD. Sometime, a simple request for a "sample" is all it takes. That's because they would rather give it to you free than to go through all the paper work of selling it to you.

And if all else fails, buy enough to cover their minimum order and sell the balance to other TMs.

Sources

Aluminum Tubing
(Truss Poles in *TM#35* and *TM#37*)

1.25" anodized aluminum tubing, 0.055" wall, 6-foot lengths only. Call Maclin-Duncan customer service



Advantages of low-tech mirror cell are many. Easy to fabricate, construction materials are readily available, all fasteners are off-the-shelf, it's very durable, can support large heavy mirrors well, reinforces the mirror box, no stress to mirror as only 18 floatation points and edge sling contact glass, low profile, mirror can be left in cell permanently, no tools needed to collimate primary, and sling can be adjusted quickly and easily. See *TM #35* and *37* for additional information.

Not drawn to scale

for a retailer near you: 800-654-8454. Also can be obtained at most Ace Hardware stores. Cost is $10 to $15 each.

1.5" non-anodized aluminum tubing, 0.049" wall, 6061-T1 alloy, 12-foot lengths only, Vincent Metals, Inc. at 800-289-8500.

No luck? Try Tube Sales, Inc. at 800-242-6802. These guys are huge and have a great variety of tube shapes and materials. If they don't have it, nobody does. Generally, you'll pay from $2 to $3 per foot. Fantastic catalog of tubing in every shape and alloy imaginable.

Double-sided Tape

Star Packaging, Inc. (I like companies with celestial objects in their name.) 800-634-0901. $1/2$" wide by 33 yards, item #CW-2570, $8 per roll. Other sizes available.

Knobs and Bondhus Balldriver Hex Tools

Reid Tool Supply, Inc. 800-253-0421. Many different knobs, handles, and odd tools. The balldriver is item #10705 $3/32$" $3/32$"L, (the L is for long) blade length is 5.5 inches, cost is only $2. Be sure to get three-button head screws or socket head screws from the hardware store first.

Threaded Inserts (Tube Connectors)

Superior Components, Inc. 708-960-1999, 1.25" or 1.5" both with $1/40$"-20 thread, #3046-4 and #3047-4 respectively. About $0.65 each. Also consider getting the series of 25 small catalogs from PMC, Pastiglide Manufacturing Corp. 213-777-8108. They make the inserts that are solid by Superior Components. Their 25 catalogs have an abundance of neat stuff.

Levelers (Collimation Knobs)

Buckeye Fasteners, Inc. 800-437-1689, item #FC 3340. They have a minimum order of 100 pieces. Cost is $0.85 each. Try asking for a sample of three, or ask whether they can give you the name of a distributor.

Felt Tabs and Floor-protector Pads (Mirror Cell Points)

As they say, "Ace is the place." Ace Hardware.

Baltic Birch Plywood (*TM#35*)

Call Allied International at 617-241-7970 for a source near you. If they can't help you, try Gorby's Wood Products, Lenin Square, Moscow, USSR. (Really!)

Sling Material and Sliders

Campmor, Inc. 800-526-4784. Good mirror sling material is 1.5"-wide, flat-black tent webbing, item #30078-E, 40 cents per foot. Other widths are available. Slider, or Fastex Lock with Wheels, item #67794-E, set of five for $2.50. Get the Campmor Catalog. It's one of the best camping supply, mail order outfits I've ever found. They have cold-weather clothing, mini flashlights, buckles, tarps, nylon fabric and Velcro by the yard, as well as many other things that amateur astronomers can use. Their prices can't be beat.

Heat Ropes

JerryCo, Inc. 708-475-8440 for their catalog. They also sell direct through American Science & Surplus Centers in Milwaukee, Chicago, and The Grande Junction, Ltd. in Virginia Beach, VA. They are a mail order warehouse with the oddest stuff. Surplus electronics, motors, fans, pulleys, gears, science things, military, magnets, optics, and many strange items of dubious value all described in a clever 50-page catalog. A must for any TM.

Riptide Ripstop Nylon Shroud

From JoAnn Fabrics. Check the Consumer Yellow Pages. If you can't find it, try Fabri-Centers of America. 216-656-2600. $6 per yard.

Kydex Light Baffle

Kleerdex Company, call 800-325-3133 for a distributor near you. Available from 0.027" thickness on up, 4x8-foot sheet $35.

Etched Virgin Teflon

Midland Plastics, 414-781-6520. 0.093 thick is $35 per square foot. Midland has a huge inventory of plastics and their catalog is a good reference.

#7181 Tweed Formica

Formica Inc. Their customer service number is 800-524-0159. $25 for 4x8-foot sheet.

#4552-50 Ebony Star

Wilsonart, Inc. Customer service number is 800-433-3222. $70 for a 4x8-foot sheet.

Glass Board

Sequenia Inc. Their customer service number is 800-637-0095. $28 for a 4x8-foot sheet.

Cam Levers (*TM#35*)

Quik-n-Easy Parts Inc. 818-358-0562. Order the lever, item #U111, and the nut, item #U112, together as a set, for $2 total.

12-Volt Cooling Fans

Skycraft Parts. 407-628-5634. Ask for their 4.25"-diameter fan, a real blower, about $15. Skycraft Parts located in Winter Park, Florida, is another candy store for TMs. If you're ever passing through the Orlando area on the way to Disney World or the Winter Star Party, plan to stop and browse here. Radio Shack also has fans.

Ladders for Big Scopes

McMaster-Carr Supply Co. P.O. Box 43355, Chicago, IL 60680-4355. In the Chicago area, phone 708-833-0300; in the Los Angeles area, 213-692-5911; in the New York area, 201-329-3200. Every ladder imaginable from little two-steppers to big double-access industrial types like the 8-foot ladder described in *TM#41*.

I have the extra heavy duty ladder, #7957T16, about $200 from catalog #94. McMaster-Carr is the largest mail order industrial supply company in the world. Their catalog is over 2,200 pages long and contains just about everything. If you would like to "page through" the ultimate hardware store, get this catalog!

Epoxy Resins

Defender Industries, Inc. 914-632-3001. Epoxy and fiberglass resins by the quart, or up to 5 gallons, Styrofoam, great varnishes, and a multitude of odd stuff for the marine industry. If you're looking into making foam-core telescope parts, get this interesting 200-page catalog.

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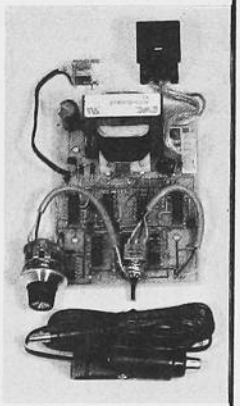

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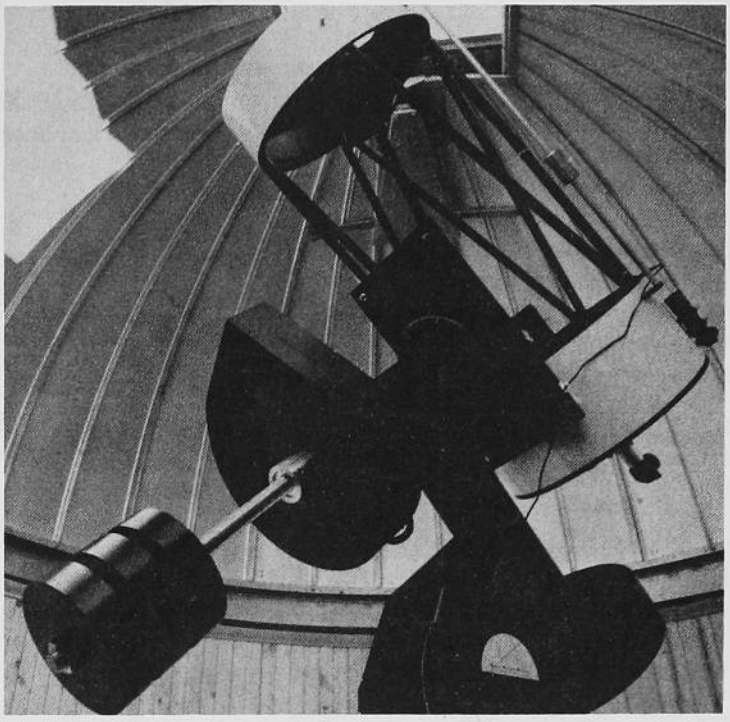

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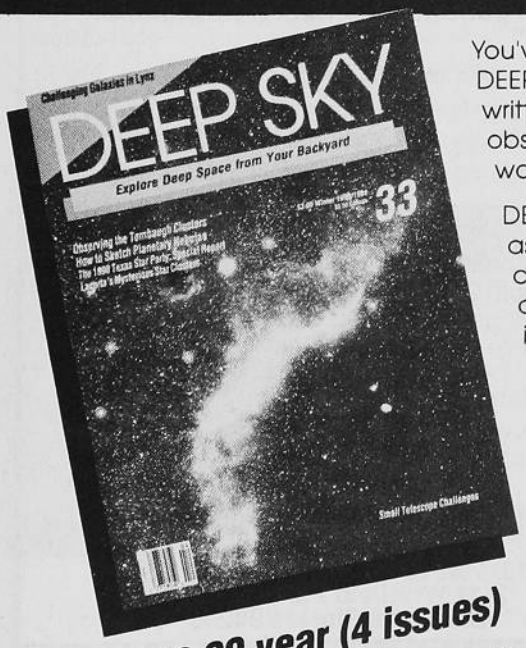

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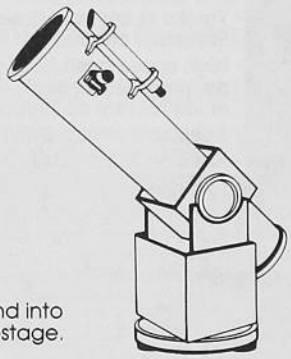

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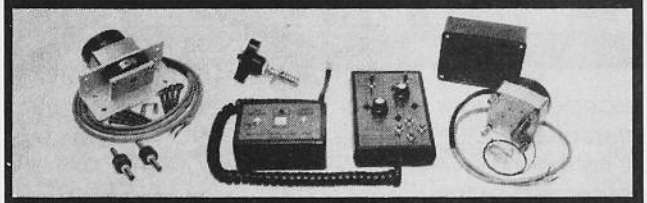

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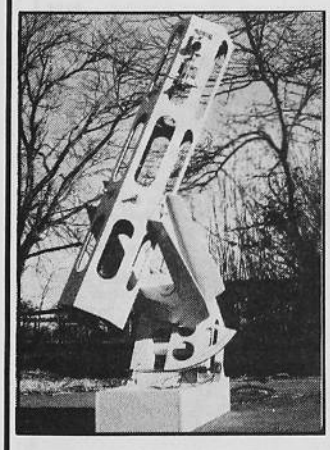

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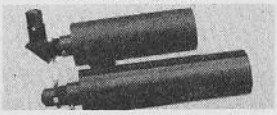

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1¼" 50mm Finderscope **$59.50**, right-angle **$89.50**
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Coma 1 inch off-axis (17½" f/4.5)

Same Field with LUMICON coma corrector lens; note smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener
2" lens **$285.00**
Extension tube for viewing **$26**
2" Easy-Guider™ (state camera) .. **$169.50**

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1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
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Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at 496nm and 501nm.

Filter Type	1¼"	48mm
Lumicon Oxygen-III	**$99.50**	**$199.50**
Lumicon UHC	**$99.50**	**$199.50**
Lumicon Deep-Sky	**$79.50**	**$119.50**
Set UHC and Oxygen-III .	**$185.00**	**$370.00**

NOTE: The Oxygen-III Filter is not a substitute, but a compliment to the UHC Filter. **1 year guarantee:** You must see nebulae with the O-III filter that are **invisible** without a filter.

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LUMICON has just designed a new adjustable piggyback mount ideal for all telescopes of 8-14" aperture. It has **both** vertical and sideways adjustment to allow optical alignment. It was designed to allow mounting of the LUMICON SUPER-FINDER on C-8, C-14, etc., but is ideal for any telephoto lenses or small telescopes.

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(State Telescope Type)
LUMICON 12x80mm SUPER-FINDER $195.00

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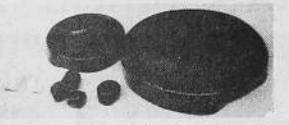

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All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms of bright guide-starts. Specify Camera and Telescope type. U.S. Patent #4,448,500

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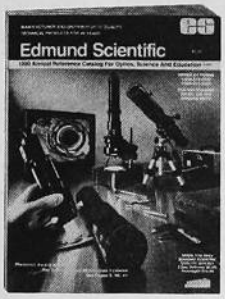

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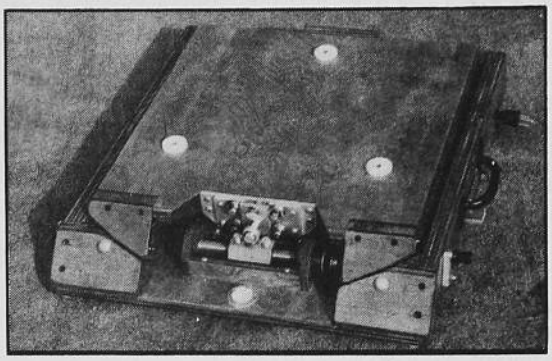

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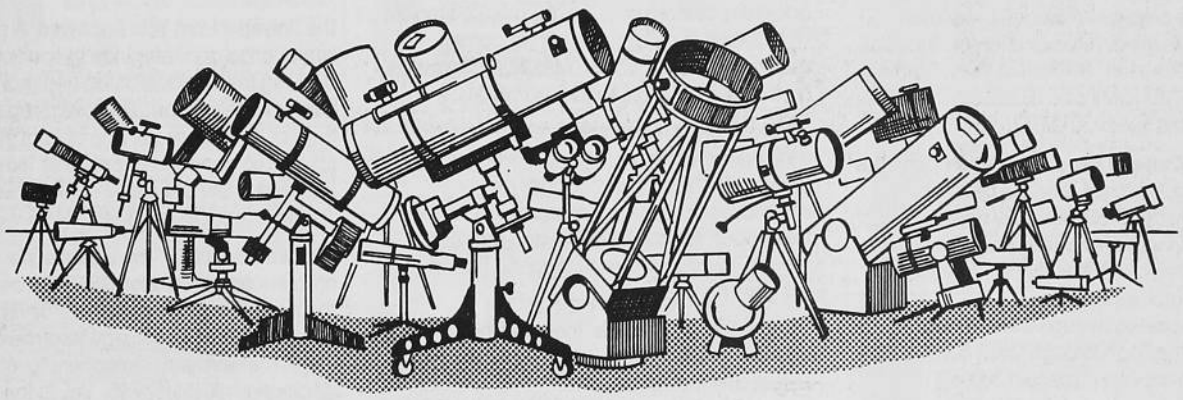

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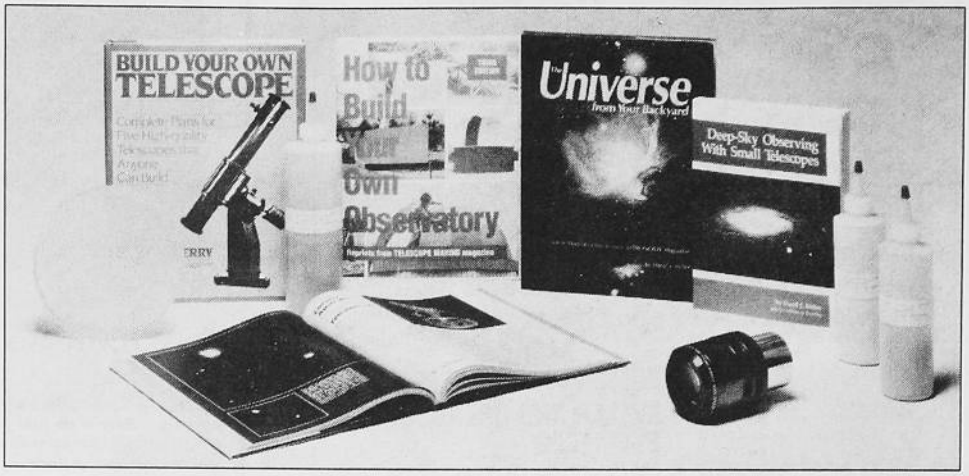

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The Universe From Your Backyard A complete introduction and reference to spotting and studying the wonders of the heavens with a backyard telescope. Find 690 deep-sky objects in 46 constellations with the help of 90 color photos, 56 duo-tone photos and 166 illustrations. By David J. Eicher, Editor-in-Chief of DEEP SKY. 188 pgs., hardcover. 18037/$24.95

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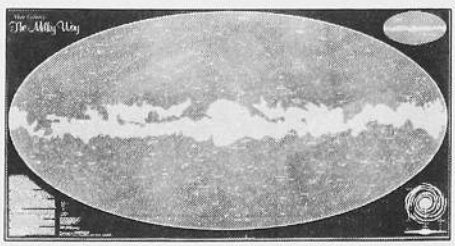

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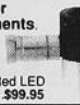

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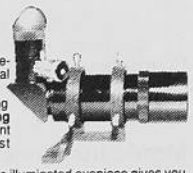

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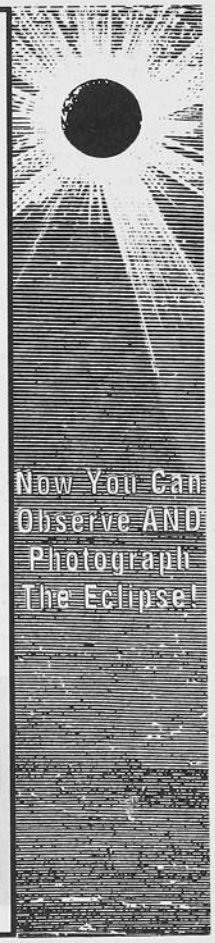

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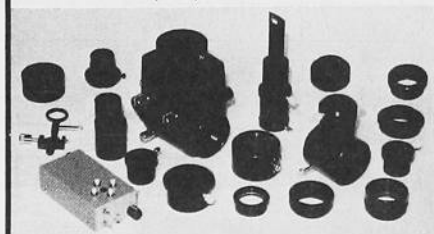

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12.5"	625	700
16.0"	1800	2050
18.0"	2400	
20.0"	3500	

LIGHTWEIGHT 2.00" THICKNESS OPTICS

MIRROR	COATING #1	COATING #2
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16.0"	1200	1450
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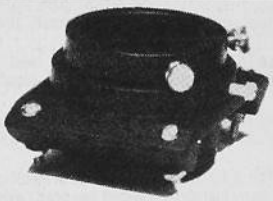

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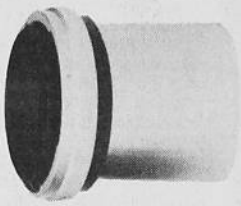

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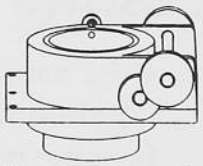

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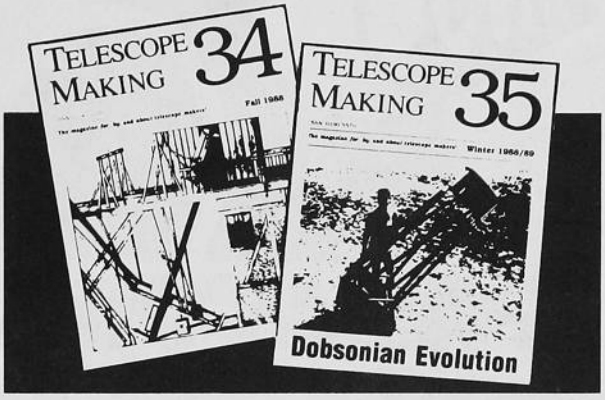

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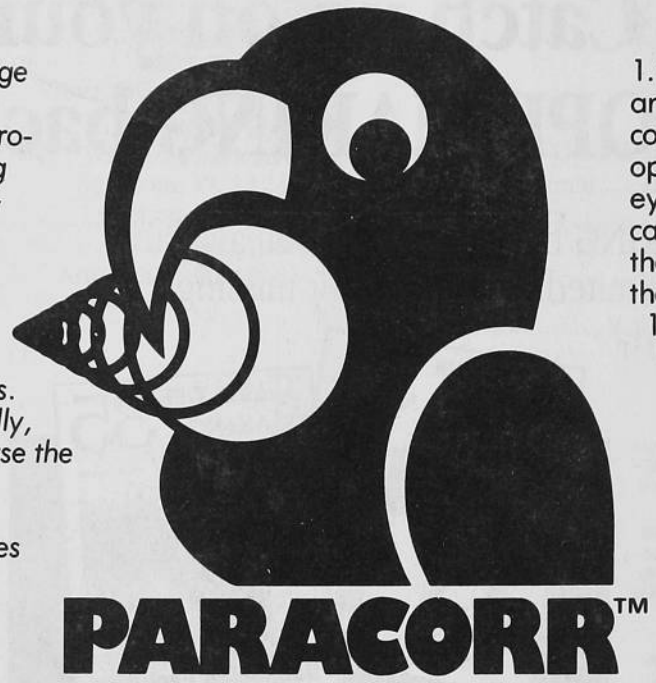

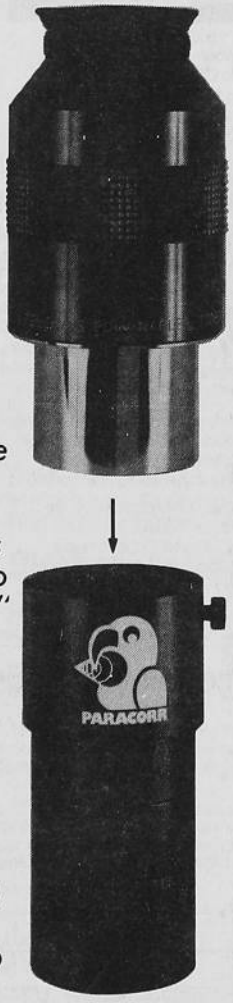

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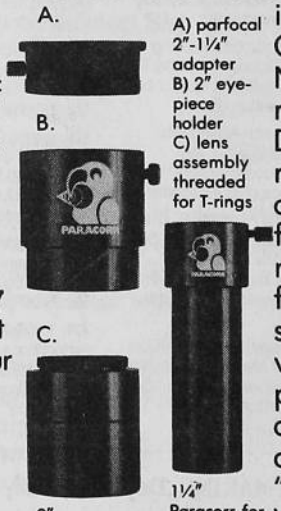

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